Jamestown Drainage and Stormwater Management Master Plan

FINAL REPORT

Prepared for:

-Town of Jamestown, Colorado

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Jamestown Drainage and Stormwater Management Master Plan





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Executive Summary

In 2016, Ayres Associates (Ayres) was selected to create a Drainage and Storm Water Management Master Plan for Jamestown to recommend improvements to the local drainage, reduce future flooding issues, and reduce debris flow impacts to the town. This funding was provided to the Town under the CDBG-DR Resilience Planning Program administered by the Colorado Department of Local Affairs (DOLA). Lithos Engineering (Lithos) served as a subconsultant to Ayres to conduct analysis and provide mitigation recommendations with regards to drainage basins that pose potential debris flow risks to the town.

With input from the community, board members, and Town staff, Ayres assessed the major and minor drainages through town, identified local drainage issues, and analyzed the creek for potential flooding and erosion potential. Drainage issues and storm water management techniques were identified and conceptual solutions are recommended to address these drainage issues. Lithos identified major drainages with potential for reoccurring debris flows and provided mitigation alternatives for those that pose a significant risk to the life and safety of the residents of Jamestown and the traveling public and a high risk of damage to private structures and town infrastructure.

These recommendations should not be considered as comprehensive design plans for debris flow mitigation systems or drainage improvements, but rather as a tool to help Jamestown officials determine where hazard mitigation funds can be most valuable.

Debris Flows

The following summarizes the general conclusions and debris flow mitigation recommendations:

- 1. Seven drainages north of and within Jamestown were identified, prioritized, and evaluated with respect to the feasibility of debris flow mitigation.
- 2. It was determined that three of the seven drainages posed a relatively high risk of conveying debris flows in the future and negatively impacting the town. The three drainages were defined as Drainage C, D, and F and had viable characteristics for the installation of ring net barriers to retain debris during debris flow events. The recommendation is for the installation of three ring nets in both Drainage C and F, and four ring nets in Drainage D.
- 3. Drainage D conveyed the largest volume of debris in 2013, dammed portions of Little James Creek, and severely impacted the main roadway through town. The presence of U.S. Forest Service land along Drainage D limits the feasibility of additional ring nets along the drainage channel, therefore, the construction of a detention basin at the base of the drainage where a new culvert is already proposed is recommended.
- 4. Opinions of probable mitigation costs for each drainage range from just over \$500,000 for Drainages C and F to almost \$1,400,000 for Drainage D.

Local Drainages

The majority of Jamestown lacks formal drainage conveyance systems, resulting in erosion issues and periodic localized flooding of roadways and structures. The recommended solutions attempt to solve multiple issues such as conveyance, local flooding, erosion, infrastructure damage, and transportation impediments while taking into account the established resiliency criteria and low impact design elements where possible.

Hydrologic modeling was performed for local drainage basins tributary to the town area. The purpose of this analysis was to determine flow rates for evaluation of existing and proposed drainage facilities at the 2-, 10-, 50-, and 100-year recurrence frequencies (rainfall-runoff events). Hydrologic subbasins were delineated using the LiDAR collected in November 2016 to provide flow rates at key locations.

Capacity of the existing drainage systems were evaluated at three locations. Culvert crossings along James Canyon Drive were evaluated with the Boulder County/ AECOM road rehabilitation project and were not re-evaluated in this study. The available capacity of these systems is presented in the following list, however these capacities do not appear to be fully utilized currently – due to bypass of flows around inlet structures. These capacities could be utilized if storm runoff is properly directed to the inlets or upstream pipe ends.

- 1. The 16th Street storm drainage system has capacity to convey approximately the 25-year flow rate.
- 2. At 12th and Mesa Streets, the existing inlet structure and 30-inch pipeline have capacity to convey more than the 100-year flow rate.
- 3. The existing Lower Main Street storm drainage system on the south side of Main Street has capacity to accept flows in excess of the 100-year flow rate.

Over 30 drainage issues were identified through community outreach and site assessments. These issues were evaluated and grouped together to form 11 projects. These projects are listed in Table 0-1 further below and discussed in further detail in the report. 30% design plans were developed for the highest priority local drainage project – the 16th Street and Andersen Hill storm sewer system (Project C1/C2/C3).

Creeks

The hydraulic analyses of the recently realigned James and Little James Creeks were performed. This analysis considered stream inflows upstream of Jamestown and mapped approximate flood inundation limits for four streamflow frequencies: the 10-, 25-, 50-, and 100-year events.

The results of the flood inundation mapping show:

- Channel bank full capacity is just below a 10-year event.
- Flows begin to come out of the channel at the 10-year event (912 cfs) between 85 and 91 Main St., flowing down the road until rejoining the channel just west of the Main St. bridge.

• Flows exit the James Creek channel at the water plant beginning at the 25-year event (1278 cfs). At this flow rate, the water travels down Ward St. until it meets the channel again at the Ward St. bridge.

The potential for channel erosion and instability was evaluated, looking for possible lateral creek migration and vertical degradation.

Downstream of the James/Little James confluence, the results show:

- Reach level bank instability would be expected to begin between the 25- and 50-year flow events (1,502 cfs – 2,095 cfs along James Creek downstream of the confluence with Little James).
- Potential minor and localized bank instability at several locations for the 10-year flow event.
- At flow events more frequent than the 10-year event (i.e. the 2-year, 5-year), the channel appears to be relatively stable.

Upstream of the confluence in both James and Little James Creek, the analysis shows:

- Reach level instability has the potential to occur at a 25-year event (1,278 cfs for James Creek above confluence, 730 cfs for Little James Creek above confluence).
- At more frequent events including a 10-year event there are many localized areas that show the potential for instability.

Because James Creek has recently undergone significant man-made changes, it can be expected that natural changes will be seen in the coming years. The creek will naturally transport material from areas of high shear stress as it finds a "new normal" condition. Recommendations for the creeks include:

- 1. Walk the entire reach at least annually and especially after high flow events to document and photograph any changes that are seen. Inspect drop structures, to identify erosion on the outer ends where it ties into the bank.
- 2. Maintain capacity in all culverts, especially those on Little James Creek by clearing out debris and sediment build up.
- 3. Install a visual flow gate on bedrock along James Creek across from Town Hall, a common gathering space, to maintain awareness of flow conditions in the creek.

Stormwater Management

Stormwater quality management strategies for Jamestown should be focused around erosion prevention and conveyance of stormwater in proper drainage systems where possible. It appears that the largest water quality issue in Jamestown is high sediment loading from local erosion due to steep slopes, concentrated flows and lack of formal or adequate drainage systems.

Recommended strategies to reduce erosion and improve stormwater quality for Jamestown include:

- Collect concentrated flows in appropriate and adequate storm drainage pipes or surface swales/ditches. (Eliminate the water sources of erosion before erosion occurs.)
- Install riprap erosion protection in areas of frequent erosion.
- Grassed swales.
- Grassed filter or buffer strips.
- For swales with erosion problems, consider riprap linings and rock checks. If this is not sufficient, a concrete swale or piped drainage system may be necessary.
- Re-vegetate barren areas and maintain healthy vegetation around surface swales.
- Consider Low Impact Development (LID) strategies that are applicable (i.e. straining based BMPs: grassed swales, and grassed filters/buffers).
- Install concrete sediment forebays where possible to trap sediment.
- Street sweeping (James Canyon Drive) and storm drain pipe cleaning (jet-vacuuming) are BMPs that may be practical for Jamestown.
- Promote pollution prevention (illegal dumping and discharges) and "good housekeeping" methods, such as covering outdoor storage and chemical storage areas.

Funding

Of the funding opportunities reviewed, there are the three opportunities recommended to concentrate on. All require meetings with the local state offices to determine eligibility and available funding programs, with additional work to prepare grant applications. These grants may be applied to the debris flow and local storm drainage projects.

- 1. Community Development Block Grants (CDBG)
- 2. EPA 319 Non-Point Pollution Control Stormwater Grants
- 3. U.S. Department of Agriculture Rural Development Grants

Community Development Block Grants (CDBG)

- CDBG Planning Grant Program (CDBG-PLNG) can provide funding to help develop strategies for addressing specific needs and help fund local plans designed to improve the quality of life of the community and/or economic development projects.
- CDBG for Public Facilities (CDBG-PF) can help fund infrastructure and public building projects.
- CDBG Public Facilities for Economic Development (CDBG-PFED) for roadway and infrastructure projects.

State administered CDBG funds are allocated on an annual basis. Eligibility research is required and applications are generally due in the fall of each year.

EPA 319 Non-Point Pollution Control Stormwater Grants

This grant support non-point source implementation projects such as constructed wetlands and erosion control/debris control projects.

EPA-319 NPS funding requires a 40% match. Projects must include the EPA Nine Elements of a Watershed-Based Plan by constructing on-the-ground BMPs to address nonpoint source impacts from selenium, pathogens and/or nutrients to waterbodies not meeting water quality standards. Further research is required to determine whether James Creek and Little James Creek meet eligibility requirements. To the extent that pathogens and/or nutrients are attached to the debris, which could be likely, this project may meet eligibility guidelines under the NPS program.

Applications are generally due by January of each year.

U.S. Department of Agriculture Rural Development Grants

- U.S. Department of Agriculture Rural Development Planning Grants can be used by local governments to develop and adopt comprehensive plans.
- Rural Development Water and Wastewater Program Grants can provide funding for community water, sewer, storm sewer, and solid waste systems.

Further discussion with the local Colorado State Office is the next step to determine what funding may be available.

Town Policy

Based on a review of the current Town policies, the following recommendations are offered:

Ordinance No. 3, Series 1994: Due to the high erosion potential throughout town:

- Consider adding language requiring existing drainage flow patterns to be addressed.
- Do not allow flat cross slopes on roadways. Require roadways to be insloped, crowned or outsloped with drainage addressed with ditches, culverts, inlets, etc.

Ordinance No. 7, Series 2004: Due to the high erosion potential throughout town:

• Consider adding language to disallow flat cross slopes on private roadways to reduce erosion potential, pothole formation, and other maintenance issues exacerbated by poorly graded roadways. Roads could be insloped, crowned or outsloped and should address drainage with ditches, culverts, inlets, etc.

Ordinance No. 2, Series 2009:

• Consider more regulatory standards to help guide development away from drainages and potential stormwater management areas. For example, required setbacks along creeks and drainages for new buildings and driveways, or requiring permanent stormwater quality best management practices for all new development or substantial redevelopment.

Ordinance No. 4, Series 2011:

- Continue to designate a local Floodplain Administrator, possibly with a contract review position.
- Provide floodplain review and enforcement as a regular part of the building permit and engineering review process for any new construction.
- Designate FEMA "Critical Facilities" in Jamestown in accordance with the criteria in the ordinance and update as warranted. As identified in the 2015 HIRA, critical facilities include the Town Hall, Fire Hall, Upper Bridge, Lower Main Bridge and the Water Treatment Plant. Additional facilities may include the school, the Mercantile.

Policy recommendations for the town include consideration of a drainage setback policy and a stormwater conveyance and quality policy, further described in the report.

On an annual basis, the Town should revisit the following items to maintain and improve drainage and stormwater management and would help keep them as a Town priority.

• Allocate budget for floodplain administration, potentially as a contract service.

- Create and maintain a capital improvements plan with a list of major and minor projects, prioritizing critical work followed by important work.
- Include drainage projects in the annual Roads and Bridges budget or establish a specific budget dedicated to drainage projects.
- Monitoring of drainage issues. It is easier to address small problems before they become major problems. Monitoring locations should include two categories of sites: stream side and local drainage. The master plan maps in the appendix of this report identify specific areas where erosion, scour, and debris collection would be most expected to occur.
- Collection and notation of new issues and reporting to Town Board on a regular basis.
- Stay current with best and new stormwater practices in Colorado.
- The Town Board of Trustees should annually re-evaluate the town policies, ordinances, and procedures to assess if they are meeting the goals of this plan.

Drainage and Debris Flow Project Summary

Table 0-1 summarizes the recommended projects including their overall prioritization scores and estimated construction costs.

Project Rank	Project Name	Description	Assessment Score	Estimated Cost
1	Debris Flow Projects - Drainage C	Series of ring net barriers	6.85	\$514,800
1	Debris Flow Projects - Drainage D	Series of ring net barriers, detention basin with concrete headwall	6.85	\$1,378,920
1	Debris Flow Projects - Drainage F	Series of ring net barriers	6.85	\$514,800
2	C2 - 16th Street	Replace storm system including pipe and inlets	3.90	\$270,100
3	C3 - 16th Street	Storm Sewer Rehabilitation	3.67	\$67,800
4	C1 - Andersen Hill	Erosion Protection	3.67	\$39,900
5	D - James Canyon Rd - High to 15th Street	Erosion Protection and storm drainage	3.20	\$85,400
6	F - 12th St Mesa to Main St.	Regrade road, extend swale	2.75	\$10,900
7	G - Buffalo Gulch Outfall	Improve culvert inlet, line channel	2.67	\$10,400
8	B1 - Merc/Town Hall	New storm pipe and inlets	2.33	\$81,900
9	E - Main St East of James Creek	Regrade Road	2.33	\$15,700
10	H - Spruce Street	Regrade Road	2.33	\$7,000
11	A - Main St Ward to Howlett's	Swale, filter strip, and inlet grading	2.29	\$53,200
12	B2 - Merc/Town Hall	Replace cross pan	2.17	\$8,400

Table 0-1. Recommended Drainage and Debris Flow Improvement Projects Summary

1.0 Introduction

In September 2013, The Town of Jamestown experienced the devastating effects of three days of heavy precipitation resulting in severe flood and debris flow damage where over 60 homes were either destroyed or damaged and residents became stranded as vital roads became impassable. The disaster also claimed the life of a community member who was killed when his home was inundated by a large debris flow. In the aftermath, federal resources were allocated by the Federal Emergency Management Agency (FEMA) to the town to conduct emergency repair work.

A Hazard Identification and Risk Assessment (HIRA) was completed for Jamestown in 2015. The HIRA recommended further assessment of the town's drainage and debris flow hazards.

In 2016, Ayres Associates (Ayres) was contracted to create a Drainage and Storm Water Management Master Plan for Jamestown to recommend improvements to the local drainage, reduce future flooding issues, and reduce debris flow impacts to the town. This funding was provided to the Town under the CDBG-DR Resilience Planning Program administered by the Colorado Department of Local Affairs. Lithos Engineering (Lithos) served as a subconsultant to Ayres to conduct analysis and provide mitigation recommendations with regards to drainage basins that pose potential debris flow risks to the town.

This report documents and presents the drainage analysis and issue identification performed by Ayres' design team. Drainage solutions and storm water management techniques are identified and conceptual solutions are recommended to address these drainage issues. The HIRA identified debris flows as posing "the most serious geologic hazard to the town in the near term." Therefore, debris flows are a significant focus of this report. Opinions for identification of the most high-risk drainage basins for future debris flows impacting the town were presented, and recommendations for possible mitigation alternatives to reduce the impacts of future events were provided.

1.1 Goals and Objectives

The goal of this master plan is to perform an assessment of the town's drainage ways and recommend solutions to address the identified drainage hazards throughout the town. Information will be provided in a user-friendly format to help the Town of Jamestown elected and volunteer officials (Town) mitigate, plan for, live through, and recover from future storm events.

The Town has begun to turn its thinking towards holistic, innovative, and integrated planning for the future and safety of the community. This vision will help the Town create and frame its own definitions of resiliency and sustainability. The Town also wants to protect the watershed through better management of storm water before it enters the creek system. The Town desires to implement low impact design (LID) solutions where possible and integrated management practices that serve the drainage and storm water management needs of the Town. The adoption and implementation of these practices will not only improve the quality of life, but also lower the impacts on town resources and the surrounding environment.

In order to help the Town recover quickly from future significant rain and snowmelt events, resiliency is an important factor to build into proposed drainage solutions. The objective is to identify drainage solutions and mitigation measures that meet as many of the following criterial as possible.

- 1. Multiple benefits. Provide solutions that address problems across multiple sectors (community, economic, health, housing, infrastructures, natural resources, etc.). It is the Town's desire to apply solutions that address multiple goals (i.e. improve habitat, reduce runoff, improve water quality, reduce nuisance issues).
- **2. Collaborative approach**. Develop and prioritize design solutions through an inclusive process that involves input and commitment from local and regional stakeholders.
- **3.** High risk and vulnerability. Ensure that strategies address and positively impact human wellbeing, physical infrastructure, and natural systems.
- **4. Social equity.** Provide solutions that are inclusive, considering fragile and vulnerable populations. These solutions should prioritize community safety through innovation and sound design concepts.
- 5. Environmental benefit. Integrate approaches that work in harmony with natural systems and improve ecological conditions, keeping perspective on overall watershed condition and impact. Proposed design options should ideally have a low impact on the environment. Fiscally and environmentally sustainable infrastructure are critical due to the limited resources and maintenance capacity of the Town to implement and maintain drainage and debris flow solutions.
- **6. Technical soundness.** Identify solutions that reflect best practices that have been tested and proven to work in similar context.
- **7. Innovation.** Advance new approaches and techniques that will encourage continual improvement and advancement of best practices.
- **8.** Adaptive capacity. Include flexible and adaptable measures that consider future unknowns of changing climate, economic, and social conditions.
- **9.** Harmonize with existing activity. Expand, enhance, or leverage previous and current local and regional planning efforts.
- **10.** Long-term and lasting impact. Create long-term gains for the community with solutions that are replicable, sustainable, and long-lasting.

The local drainage system in Jamestown is like many mountain towns, set along steep terrain and dirt roads that create challenging conditions to handle rain and snow melt runoff. Evaluating and improving the local drainage system is important to the town as it can reduce the regular volunteer maintenance required and address nuisance drainage issues that occur frequently.

The purpose and scope of this project is to create a drainage and storm water management master plan for the Town of Jamestown and immediate upstream tributary drainages. The proposed plan will provide specific guidance to the Town of Jamestown to manage flood control, mitigate drainage and debris flow impacts and to implement storm water management techniques to address issues associated with runoff including sedimentation and mine waste.

1.2 Acknowledgements

We would like to acknowledge the following people for their contribution and valuable input to this master plan.

- Town of Jamestown community
- Town of Jamestown Board of Trustees:
 - o Tara Schoedinger, Mayor
 - Michael Box, Trustee
 - Carolyn Donadio, Trustee
 - o Chad Droste, Trustee
 - o Vic Harris, Trustee
 - o Ken Lenarcic, Trustee
 - o Heather Yahnke, Trustee
 - o Jennifer Lucas, former Trustee
- Town Staff:
 - o Erika Archer, Assistant Flood Recovery Manager
 - Jon Ashton, Water Operator
 - o Millissa Berry, Town Planner
 - o Tessa Brandt, Finance Clerk
 - o Julie Fischer, Finance Clerk
 - o Emma Hardy, Water Operator
 - Chris Krolick, Finance Specialist
 - Kristi Rutledge, Town Clerk
 - o Phillip Strom, Recovery Project Manager
 - o Mark Williams, Floodplain Administrator
- Logan Sand, Recovery and Resilience Planner, Department of Local Affairs (DOLA)

2.0 Project Background

2.1 Site Description

Jamestown is a small mountain community of about 275 people located in the foothills of Boulder County approximately 12 miles northwest of the City of Boulder. The terrain in and around town is mountainous with steep slopes and James Creek and Little James Creek run through the middle of town. See Figure 2-1 for a project location map. The town has a history of flooding and the setting lends itself to slope related hazards – particularly those related to drainage. In addition to flooding, the area is prone to wildfires which also impact drainage and water quality. Jamestown is positioned along the south base of Porphyry Mountain, a quartz monzonite intrusion that includes a landform above Town that has been identified as a fast-moving rock avalanche. There are several drainage basins that initiate on Porphyry Mountain and terminate at Overland Road, a continuation of James Canyon Drive and Main Street. In October 2003, over 3,500 acres of private and U.S. Forest Service (USFS) land were burned in the Overland Fire within Jamestown area. The burn area covers portions of Porphyry Mountain. Recent reports and historic accounts identify debris flows as a major hazard that has impacted the Town since the late 1800's after it was incorporated in 1883 (Hazard Mitigation Plan-Boulder County, 2015).



Figure 2-1. Project Location Map

Jamestown is also located within a mining region. Although many mines are no longer in operation, mine tailings are still a concern. The threat of contamination from mine waste compounds the potential for water quality issues beyond just the sediment and debris coming off the slopes. Past mining operations also contribute to debris flow potential and slope stability issues.

Addressing drainage is a significant need for the town as landslides, debris flows, and storm water runoff from the slopes lead to serious impacts. Examples of such impacts were witnessed during and after the 2013 flood event that hit the area. Not only did flood waters cause damage but mud slides, debris slides, and storm water runoff from the hillsides contributed to severe property damage. Many drainages were severely impacted and/or shifted due to the volume of water coming down the hillsides and new drainage paths were created. After the flood, immediate issues with a few drainages were addressed. However, long term solutions have not been planned or implemented and other drainage ways still need to be evaluated and addressed. The condition of slopes, vegetation, and soils as a result of the 2003 Overland Fire contributed to the level of debris that was deposited in town during the 2013 flood.

The Town currently lacks an extensive drainage and storm water management infrastructure system. The existing system is a mix of culverts and road side ditches that help direct runoff. Many of the roads in town are not paved which can contribute to erosion along the roads but also slow down and absorb some of the storm water before it reaches the creeks.

The Town has limited budget for maintenance and improvements, therefor outside funding sources are most likely needed to implement proposed town improvements.

2.2 Drainage Ways

The major drainage ways affecting the town include the gulches along both the northern and southern side of town and both James Creek and Little James Creek. The primary hazard along the gulches is the potential for debris flows during large storm events. James Creek and Little James Creek comprise the other major drainage ways that collect water and debris from the gulches along the canyon and convey flows through town. Minor drainage ways exist within town as well, which contribute to localized flooding, erosion, nuisance issues, and maintenance issues.

2.2.1 Major Drainage Ways – Debris Flow Hazards

Debris flows are geologic hazards defined as fast-moving landslides that generally occur during periods of intense rainfall and/or rapid snowmelt. Debris flows often occur rapidly with little warning and have the potential to destroy infrastructure, property, and put lives at risk. They typically initiate on steep hillsides and liquefy as they accelerate downslope at speeds up to 35 mph. Water, sediment, boulders, trees, and even structures can be mobilized in a debris flow. The destructive power of debris flows can wash out homes, roads, and bridges as well as create dams in streams. The precipitation threshold required to trigger a debris flow is often lowered in areas that have recently been burned by forest fires (Highland et al., 2016). Canyon bottoms, stream channels, roadcuts, and canyon outlets are particularly hazardous areas for debris flows.

In the Hazard Mitigation Plan (HMP) for Boulder County, refined in 2015 to fulfill FEMA requirements, debris flows in the county were defined as having a limited geographic extent (less than 10% of the planning area), an occasional probability of future occurrences (reoccurrence interval of 11 to 100 years), limited magnitude (10-25% of property severely damaged), but a high significance (widespread potential impact). Terrain impacted by forest fires often has increased potential to produce excessive, easily mobilized sediment, which can result in higher debris flow potential during storm events. Typically, burn areas are at a higher risk for slope instability (landslides, debris flows, etc.) in the 2-5 years following the burn event. According to reports, multiple landslides and/or debris flows occurred north of town between the burn area and James Creek between June 2004 and 2008, prior to the 2013

flood events. The southern slopes of Porphyry Mountain do not appear to have recovered significantly since the 2003 wildfire, most likely due to the steep slopes. Visual inspection and review of aerial and satellite imagery by Lithos revealed slopes directly above the town have significant quantities of loose material that can easily mobilize during precipitation events, resulting in debris flows of varying magnitudes.

2.2.2 Major Drainage Ways – James and Little James Creeks

The source of the James Creek drainage extends toward the Continental Divide west of the town. From its headwaters, James Creek flows east for approximately 7.8 miles before entering Jamestown. The source of the Little James Creek extends west of town. From its headwaters, Little James Creek flows east for approximately 2.0 miles before entering Jamestown. The James Creek basin drainage area at the town center, downstream of the confluence of Little James Creek is over 12 square miles.

Throughout Jamestown, the creek channel is within a steep canyon that opens slightly through the town and then tightens up again downstream of the town. The channel bed has a very steep slope (approximately 5%) that is armored with large cobble to boulders with a varying channel width from about 35 to 50 feet. The channel banks are very shallow with some vegetative cover of trees and grass along with exposed relatively unvegetated earth.

This reach of James Creek is designated by FEMA as a Zone AE floodplain, which can be found on Boulder County Flood Insurance Rate Map Panel number 08013C0357J. The 100-year floodplain width varies between approximately 80 and 280 feet in the Town.

Floods in the Jamestown area usually occur during the period of May through September. Mountain snowmelt in May and June contributes significant runoff, but serious flooding does not occur unless rainfall accompanies the snowmelt (2012 FIS). Peak flooding will usually occur within a few hours after a single rainfall event. Flooding is generally of short duration, but may be prolonged significantly by snowmelt runoff.

In Jamestown, the steep stream slopes create swift currents during a flood, which produce added damages. Debris carried by the fast-moving water not only threatens bridges and culverts, but can damage houses and other structures in the floodplain. The bridge and culvert crossings often result in channel restriction, raising the water surface elevations. Erosion undercuts and destroys structures that would otherwise receive little damage from inundation. Large quantities of rock are often deposited in portions of the channel.

There is a history of flooding in Jamestown. In June 1894, a flood roared down James Creek and washed away much of the low-lying area of the town. Heavy rains accompanied by heavy spring runoff caused the flood. Most of the houses on the north side of Main Street were ruined or washed away, as was much of the road.

A similar flood occurred in August 1913, damaging or destroying almost every house along James Creek. All wagon bridges and footbridges were destroyed, and it took two weeks to open the road to traffic.

In August 1955, a brief cloudburst, lasting approximately 30 minutes, damaged four bridge and culvert crossings along James Creek and deposited several inches of mud in local residences.

Jamestown was also flooded in 1965, and again in May 1969, following three days of heavy snow and rain. The floodwaters left the normal channel, destroying a number of buildings and the town water supply (Jacobs, 2014).

In September 2013, the Colorado Front Range experienced an extensive rainstorm event spanning approximately ten days from September 9th to September 18th. The event generated widespread flooding as the long duration storm saturated soils and increased runoff potential. Flooding resulted in substantial erosion, bank widening, and realigning of stream channels; transport of mud, rock and debris; failures of dams; landslides; damage to roads, bridges, utilities, and other public infrastructures; and flood impacts to many residential and commercial structures (CWCB 2014). The Town of Jamestown experienced nearly a 500-year flood event (estimated to be 4,800 cfs) through town, destroying the Andersen Hill Road bridge, and clogging the Lower Main Street bridge with sediment and debris. This caused the channel to flank the bridge to the south, moving water and sediment down Lower Main Street.

2.2.3 Minor Drainage Ways – Local Drainages

Local drainage issues occur throughout town due to the steep terrain and rural infrastructure that generally consists of dirt roads, roadside swales and minimal drainage infrastructure. The steep canyon topography through town creates areas of fast flow and erosion potential as runoff makes its way through town, alongside roadways and into the creek. These minor drainage ways tend to create nuisance flooding and erosion issues for residents and the traveling public during rain events.

Most of the previous hydraulic analysis work in town has focused on the creek system following the 2013 floods. However, there have been several improvements designed and/or constructed to address local drainage issues. Gillespie Gulch is a major drainage through town, however it impacts adjacent local drainages. Drainage improvements for Gillespie Gulch have been designed and are expected to be constructed during late summer/fall of 2017. An adjacent inlet and culvert have been constructed on Mesa Street in preparation for construction of the Gillespie Gulch improvements. Drain inlets and connecting storm sewer pipelines have been constructed on the south side of Lower Main Street, a bit west of 12th Street. Most recently, a culvert was installed along the west side of 16th Street between Mesa Street and Andersen Hill Road.

The James Canyon Drive Permanent Repairs project, designed by AECOM, focuses on repairing flood damaged road sections along James Canyon Drive. In addition, it addresses some of the drainage deficiencies along the north side of James Canyon Drive with proposed culvert crossings and inlet improvements. These road crossing drainage improvements are sized to meet Boulder County Design criteria, to pass the 10-year design event without overtopping and the 100-year event with less than 1 foot of roadway overtopping. The project began construction in the summer, 2017.

With much of the drainage basins north of James Canyon Road already addressed by the James Canyon Drive Permanent Repairs project, the assessment of local drainage issues focused primarily on the south of James Canyon Road.

3.0 Drainage Investigation

3.1 Update Topographic Data – LiDAR Mapping

To better understand and analyze the potential risks to the town, Ayres collected new LiDAR topographic data in the Fall of 2016. Ayres Associates collected airborne LiDAR (Light Detection and Ranging) data in early November 2016 to provide highly accurate elevation data throughout the project area. The data was collected from a fixed wing aircraft at a density of 2 points per square meter with a nominal post spacing of approximately 0.7 meters, resulting in a vertical accuracy of 10cm RMSEz. Ground control survey was conducted at four locations dispersed throughout the project area for LiDAR calibration and accuracy verification.

The resulting raw LiDAR dataset was then run through Ayres Associates' data production process in order to create the final set of deliverables. Hydroflattening breaklines were created along all waterways, the LiDAR point cloud was classified and a new digital elevation model (DEM) was created. Lastly, 1-foot interval contours were generated from the new elevation surface and metadata was provided for all deliverables.

3.2 Previous Work

Ayres and Lithos reviewed the Hazard Identification & Risk Assessment, Housing and Land Use Analysis (HIRA) Report produced for the Town by Leese & Associates in 2015. The authors of the report recommended that development be avoided in debris flow areas until a team of hydrogeologists, geologists, and geotechnical engineers can assess the probability of future debris flows in the drainage basins identified in their report. The report identified approximately 30 basins capable of producing debris flows with the potential to impact the town and recommended that mitigation efforts be taken as a result of the investigation to protect existing structures from future debris flow events. The HIRA report states that "debris flows pose the most serious geologic hazard to the town in the near term" with "about 13% of the town within debris flow hazard areas."

Additionally, the HMP identified debris flows as one of the most significant hazard for Jamestown. The report identified the Fire Hall, Town Hall, and the Water Treatment Plant in Jamestown as critical facilities, the protection of which should be prioritized in order to minimize the loss of essential services following a hazard event. Currently, the three critical facilities are in areas potentially impacted by debris flows. The HMP also identified the Andersen Hill bridge, property acquisitions, dwelling elevations, and Gillespie Gulch Culvert as high priorities for hazard mitigation. The HMP lists the acquisition of properties damaged in the September 2013 precipitation and flood event as a high priority for Jamestown. Property acquisitions would be used to remove development from hazardous locations and enforce the compliance of any redevelopment and recovery efforts with existing development codes. The report was supportive of mitigation efforts and cited a congressional study (no reference provided) that found that each dollar spent on mitigation saves four dollars in future losses.

Locally, the Jamestown Mayor and Board of Trustees have stated their commitment to continuing the implementation of floodplain management practices and participation in the National Flood Insurance Program (NFIP) which allows private property owners to purchase affordable flood insurance and allows the Town to be eligible for federally backed monetary support and disaster relief funds. Following the 2013 precipitation and flood event, a Natural Resources Conservation Service (NRCS) grant designated

for emergency watershed protection was used to improve the portion of James Creek that flows through town. Improvements include riparian and floodplain reconfigurations using bioengineered structures to reduce flood water velocities and scouring effects for 25-year flood events. A culvert for Little James Creek was also replaced in October 2014. Recently, the Town has hosted educational programs for the community by the Environmental Protection Agency (EPA), USFS, Boulder County Health, James Creek Watershed Initiative, and Left Hand Watershed Oversight Group.

Ayres and Lithos also reviewed a 2016 memorandum compiled by AECOM for Boulder County with regards to the hydraulics design in James Canyon Drive and associated flood recovery. Peak flow analysis was conducted for drainage basins corresponding to existing and temporary culverts. AECOM proposed additional culvert locations for corresponding drainage basins. In total, the hydrologic properties of over 50 basins along the James Canyon Drive area were calculated. Only 26 of those basins were considered for culvert sizing, 11 of which were associated with Jamestown. The authors of the memorandum reported that many drainage paths in the survey area either did not have existing culverts or the culverts were placed in suboptimal locations. They recommended placing cross culverts where drainages meet the road rather than allowing water to flow parallel to the road. AECOM sized all cross culverts in accordance with Boulder County requirements to pass 10-yr flows without overtopping and to convey 100-yr flows with less than 1 foot of roadway overtopping.

3.3 Site Visit - Visual Assessment

3.3.1 Debris Flow Drainages

During the 2013 flood event, debris flows were triggered in at least five of the drainage basins north of Town. The debris flows conveyed over 30,000 cubic yards (yd³) of saturated sediment, boulders, and other debris with a lot of the material entering Little James Creek, temporarily damming portions of the creek, and continuing downstream. The Overland Fire in 2003 was determined to be a contributor to the severity of the debris flows in 2013 (HIRA, 2015). Main Street was reportedly closed up to four times between 2004 and 2008 due to debris flows initiating from the burn area despite restoration efforts. The precipitation and flood event that occurred in September 2013 has since been described as a 500 to 1,000- year event. Therefore, it can be reasonably postulated that the drainages that conveyed debris flows as a result of the precipitation event in 2013 are likely to convey debris flows in the future. Conversely, drainages that did not convey debris flows in 2013 can be considered to have a relatively low risk of conveying debris flows in the future, unless a similar or larger precipitation event is realized.

During the 2013 events, several drainages upstream of the water treatment plant experienced debris flow events which introduced significant amounts of debris into James Creek. The locations of the drainages are not in areas impacted by wildfire and are remote compared to those on the slopes of Porphyry Mountain, directly north of the Town. The likelihood of future debris flows from those drainages and other drainages in the area that have not experienced debris flows during a 100-year precipitation and flood event are remote and were therefore not included in the analysis and recommendations.

During Lithos' visual and preliminary measurements of five drainages north of town, Lithos identified two additional drainages as a result of the HIRA report, and included those as priorities for evaluation of debris flow mitigation. The seven priority drainages, designated in this report as Drainage A through G (Figure 3-1), have a potential to convey debris flows in the future and pose a high risk to life and safety as well as a high risk to negatively impact the Town. The priority drainages were chosen based on

historical research, communication with Town officials, the HIRA report, the HMP, community input, and our site investigation.

Ayres performed a topographic comparison of LiDAR data collected by Boulder County in 2011 (preflood) and by Ayres in 2016 (post-flood) for the area north of town. The results of the comparison are shown in Figure 3-2 and only negative differences, or elevation losses, are depicted. The elevation comparison revealed significant elevation changes (seven feet or more of elevation loss) occurred in four of the priority drainages. Changes of less than two feet were removed to eliminate noise from vegetation and seasonal fluctuations It is reasonable to assume a majority of the elevation changes observed in the drainage channels are the result of the 2013 debris flows, therefore, the LiDAR comparison data as the estimated 2013 debris volumes conveyed by each drainage was used. The actual debris volumes could have been slightly larger, or smaller than what was estimated using the LiDAR data. It is important to note the LiDAR volumes do not include water, which we assumed to be approximately 30% of the total debris flow volume. Significant changes in topography between 2011 and 2016 were also observed in the rock avalanche landform (see Figure 3-2) on Porphyry Mountain which indicates it is still active.





3.3.2 Town Local Drainage

Local drainages throughout the town typically consist of roadside ditches, at grade road crossings, culverts and drain inlets. A site visit of the local drainage ways in town was conducted on November 9, 2016 to have a firsthand look at the town's drainage systems and drainage issues. In addition to visual inspection of existing drainage infrastructure, Town staff provided valuable insight to the nature of some of the drainage issues. A number of community members shared their experiences from the 2013 flood event and discussed drainage issues they have encountered. Anecdotally, many of the local drainage issues are not a result of the recent flood event, but on-going drainage problems experienced by the community.

Several follow up visits were made to supplement the initial visit in order to understand local drainage infrastructure and issues. The majority of piped infrastructure consists of corrugated metal pipe with open ends. Several grated inlets exist along 16th Street, near the school, along Mesa Street, and at 12th Street. Runoff flows overland until it reaches a roadside ditch, an inlet, or a culvert where it is directed to another ditch, inlet or culvert and eventually to the creek.

3.3.3 James Creek and Little James Creek

Little James Creek and James Creek will be the final recipient and conveyance channels for all storm water within the project area. Previous efforts to assess the Emergency Watershed Protection Phase 1 channel restoration work, and make recommendations to increase resiliency along the channel, was completed by Lynker Technologies in 2016.

As part of the project, a site visit was conducted along both channels to understand post flood conditions of the banks, channel, new drop structures, and bridge/culvert crossings. Site photos are included in Appendix A.

Flood recovery work along the channel included bank stabilization, drop structures, and floodplain widening in some locations. Most of the discussion below pertains to James Creek and includes portions of Little James Creek near the confluence and upstream near the Overland Road culvert crossing.

Bank revetment appears to be located along all banks next to roads, homes, and near bridges and provide some level of lateral stability to the channel. During the site visit, the depth of the revetment was not known, and a review of design plans did not provide information related to the toe down depth. The long-term stability of the bank revetment will be dependent, in part, on if the depth of revetment is sufficient to protect against potential scour along the bank. Other factors impacting long term stability of bank revetment include appropriate use of filter layers, appropriate sizing for design flood event, and establishment of riparian vegetation within the bank.

Drop structures were constructed throughout the project area along James Creek. The long-term stability of the channel will be impacted by the performance of these structures. Drop structure stability will be dependent on appropriate rock size, depth within channel, and key-in extent into banks. If drop structures begin to fail during high flow events, channel instability could negatively impact adjacent infrastructure.

All crossings, including culverts, local access bridges, and primary bridges, constrict the channel and floodplain during high flow events and present the potential for debris accumulation, roadway overtopping, and flow redirection.

The creek corridors appear sufficient to convey typical yearly flows from snow melt and normal rainfall, especially as riparian vegetation continues to establish throughout the corridor. However, the performance of the flood recovery efforts are unknown and therefore monitoring and maintenance of bank revetment, channel drop structures, and crossings is advised during high flow events.

3.4 Community Outreach

Community outreach consisted of a series of Town Board of Trustees meetings as well as Community Meetings at Town Hall. Additionally, project site visits provided opportunities to talk one-on-one with town members as the consultant team walked through town during site visits. Town staff provided input based on local understanding of town issues and interaction with the community as they received input. The community meetings and board meetings are summarized below.

A project kickoff meeting was held in November 2016 with town staff to discuss the project scope and perform an initial site visit. A community meeting was also held in November 2016 with the primary goal of gathering information from community members about drainage issues and concerns they have experienced through town.

In December 2016, the board meeting was attended to introduce the engineering team to the Town Board members along with gathering input and information they had regarding drainage issues throughout town.

Another round of community and board meetings were held in March 2017 to discuss drainage issues being analyzed and the initial prioritization criteria developed to assess and prioritize each drainage issue and resulting conceptual solution. These meetings generated input on the prioritization criteria and priorities for the town.

A final community meeting was held at the end of May 2017 and another board meeting in early June 2017 to discuss recommended drainage projects and results from the prioritization process.

At a final board meeting in August 2017, the master plan was adopted by the Town.

4.0 Evaluate Existing Conditions

4.1 Evaluate Priority Drainages – Debris Flow

At least half the length of all the priority drainages are located on USFS land, which makes the installation and maintenance of mitigation systems more challenging. While this did not control the mitigation feasibility analysis for the priority drainages, it was a continual consideration, which is further discussed in Section 5.1. The overall goal was to provide the Town with realistic and economical mitigation recommendations that reduce the damaging impacts of debris flows to the community. Therefore, where possible, the feasibility evaluation and mitigation recommendations were confined to non-USFS land where possible.

Despite the high intensity and short duration rainfall during the 2013 precipitation event, Drainages A and B did not produce debris flows. Additionally, Drainages A and B exhibited little-to-no measurable decreases in elevation between 2011 and 2016 and appeared to be well vegetated. Therefore, Lithos determined Drainages A and B were relatively low-risk drainages such that non-construction methods, described in Section 5.1, are likely to be sufficient to reduce potential damage of future debris flows in those drainages.

During the site investigation, Lithos evaluated Drainages C, D, E, F, and a limited portion of G. Current drainage conditions were recorded with field observations and photographs and relevant photographs are presented in Appendix A. Drainage E was relatively narrow and shallow with the debris run-out terminating at a break in slope above a private home and exists exclusively on USFS land. The LiDAR comparison determined a net volume loss of 870 cubic yards occurred in Drainage E between 2011 and 2016. The current geometry of Drainage E would make the installation or construction of mitigation techniques difficult and likely ineffective. However, this drainage should be monitored for future changes and proper safeguards are recommended for structures immediately downstream.

For Drainage G, the team primarily relied on aerial and satellite imagery, LiDAR comparison, and observations of the drainage from James Canyon Drive. The LiDAR comparison revealed the vast majority of volume change occurred at higher elevations in Drainage G with impacts primarily to private driveways and/or a roadway outside of the Town limits. Mitigation efforts are recommended for Drainage G to reduce negative impacts on landowners, however this drainage is not considered a high risk priority drainage for the Town due to a minimal footprint and impact within the town limits. Lower elevations of the drainage are on USFS land and appeared to be well-vegetated and therefore can be considered relatively stable. No additional mitigation efforts are recommended for Drainage G aside from non-construction methods described in Section 5.1.

The site investigation revealed significant debris and scarring in Drainages C, D, and F, with impacts of debris flow deposits visible along Main Street and Overland Road. The LiDAR comparison revealed net volume losses of 8,030 yd³, 16,220 yd³, and 4,850 yd³ occurred in Drainages C, D, and F, respectively. Based on records of the 2013 event, debris flows conveyed in these three drainages caused major devastation to roadways and resident safety, with a debris flow in Drainage F responsible for claiming the life of a Jamestown resident. Therefore, these three drainages have been identified by Lithos as the high risk priority drainages and long-term mitigation techniques should be implemented as soon as possible. During the site visit, the three high-risk drainages contained considerable debris (i.e., felled trees and sediment including large boulders) at higher elevations and weathering on Porphyry Mountain

appears to produce a somewhat consistent source of rock debris. Therefore, we believe there is a high likelihood Drainages C, D, and F will convey debris flows in the future.

Due to the relative risk of reoccurrence and the damaging effects of debris flows to a major roadway and residents, Lithos considered various techniques for debris flow mitigation including mulching, seeding, log berms, ring nets, check dams, and detention basins. Vegetation did not appear significantly depleted from the 2003 fire. However, taking the natural vegetation into consideration along with the steep slopes and failed restoration efforts in the past, mitigation through mulching and seeding likely will have little impact on debris flow mitigation. Additionally, meticulous planning and relatively high maintenance is often required for log berms and check dams to effectively mitigate debris flows. Ultimately, it was determined ring net barriers to be the most feasible and effective option to reduce the debris flow hazard. Factors contributing to the conclusion include favorable channel geometry and ring net characteristics such as performance, strength, ease of installation, longevity, and cost. Lithos is recommending the installation of ring net barriers in the three identified high-risk drainages. Constructing a sizeable detention basin at the base of Drainage D to reduce potential impacts of debris to the roadway and Little James Creek is also recommended.

4.2 Hydrologic Model of Town

4.2.1 EPA SWMM Hydrologic Model

Hydrologic modeling was performed for local drainage basins tributary to the town area. The purpose of this analysis was to determine flow rates for evaluation of existing and proposed drainage facilities at the 2-, 10-, 50-, and 100-year recurrence frequencies (rainfall-runoff events). Modeling was performed in the EPA Storm Water Management Model (SWMM) version 5.1.012.

This analysis did not include drainage areas upstream of Jamestown, along James or Little James Creeks, that do not intersect the town area before discharging into the streams. The downstream limits of the SWMM model was James and Little James Creek.

4.2.2 Hydrologic Model Parameters

Rainfall hyetographs for the SWMM model were developed using the Urban Drainage and Flood Control District (UDFCD) 2-hour design storm distribution, as documented in Chapter 5 of the UDFCD Drainage Criteria Manual (DCM). The 1-hour point precipitation values were obtained from NOAA Atlas 14. Depth reduction factors for larger watersheds (greater than 2 sq. mi.) were not applied. Rainfall depths and design storm hyetographs are provided in Appendix L.

Hydrologic model subbasins were delineated using the LiDAR data collected in November 2016 and were subdivided as necessary to provide detailed results at key locations.

Subbasin parameters for the EPA SWMM model were developed based upon available data, standard values from the UDFCD and Boulder County DCMs, and engineering judgement as necessary. The process for development of the individual subbasin parameters is briefly described as follows.

• Imperviousness values were determined subjectively based upon vegetation and ground cover from aerial imagery and cross referencing these observations with the UDFCD and Boulder County DCM imperviousness tables. Imperviousness values and a subbasin imperviousness map can be found in Appendices K and L.

- Subbasin Slope was measured from the LiDAR data along the main flow path.
- Infiltration values were developed using USGS soil map data combined with the UDFCD infiltration rates by hydrology soil grouping. Weighted averages of hydrologic soil group and corresponding infiltration rates were determined for each subbasin.
- Depression storage and overland flow roughness values were obtained from standard values from the UDFCD and Boulder County DCMs as well as EPA SWMM standard guidance.
- The subbasin width parameter was determined by dividing the subcatchment area by the main channel flow length.

Subbasin parameters and subbasin maps are presented in Appendices K and L.

Model routing elements were created along identified surface flow paths and defined using several categories of typical cross sections.

4.2.3 Hydrologic Model Calibration

The EPA SWMM model was calibrated by comparing the model peak discharge results to flow rates from published in previous studies. Based upon the hydrologic review and analysis provided in the 2016 AECOM study for James Canyon Drive Flood Recovery, it appears that sub-watersheds north of James Creek, and less than 100-acres, have unit discharge values of approximately 2.5 cfs/ acre (100yr) and 0.8 cfs/ acre (10-year), on average.

Using this information, hydrologic model subbasins on the north side of James Creek were calibrated to provide results consistent with these prior studies. This calibration was accomplished primarily by increasing the imperviousness percentage of the individual subcatchments to a value of 20 - 25%. This adjustment appears reasonable as these drainage areas contain thin forest, barren areas, and rocky outcroppings.

Information for calibration of the drainage areas south of James Creek was not available. However to be consistent with the model impervious adjustments made north of James Creek, the imperviousness values for southern drainage subbasins were also increased to 8% and 12% impervious. These impervious values are slightly lower than those north of James Creek, which is representative of the heavier forest in these areas.

The final calibrated hydrologic model results are documented and presented in Appendix L.

4.2.4 Hydrologic Results at Key Locations

Table 4-1 below presents the SWMM model hydrology results at key locations.

		Project	SWMM	VI Peak Discharge (cfs)				
No.	Location	Letter	ID	100-yr	50-yr	25-yr	10-yr	2-yr
	Drainage Crossing - 200' Upstream of							
1	Main St./ Ward Street Intersection	Α	233	10	6	3	2	1
2	Howlett's Gulch	А	315	76	52	38	29	17
3	Behind Town Hall and Mercantile Bldg.	В	SB-106	22	13	7	6	3
4	In front of Town Hall and Mercantile Bldg.	В	239	30	18	11	9	5
5	16th Street - by propane tank (Upstream end of storm system)	С	213	25	12	9	6	4
6	16th Street - South of School	С	279	20	13	10	7	4
7	16th Street and Mesa Street	С	280	36	22	14	11	6
8	16th Street at Pipe Outfall	С	208	35	20	15	11	6
9	16th Street and Spruce Street - SE Inlet	с	283	1.6	0.7	0.4	0.3	0.2
10	Mesa Street - NW of School	С	202	15	8	3	2	1
11	Andersen Hill - Swale at James Creek	С	330	5	4	3	2	1
12	High Street - Behind Fire Department	D	242	95	59	42	32	18
13	Main Street - in front of Fire Department	D	335	107	66	49	37	20
14	James Canyon Drive - at Exist. 18" Culvert	D	245	119	72	55	41	21
15	Main Street (west of 12th St.) - Storm System Inlet	E	273	10	7	6	4	3
16	Main Street (west of 12th St.) - Storm System Junction/ Inlet	E	274	13	9	7	5	3
17	Main Street (west of 12th St.) - Storm system outlet/ outfall swale)	E	272	16	10	8	6	4
18	Mesa Street flows at 12th Street (west side only)	F	161	18	9	4	3	2
19	Gillespie Gulch at Mesa Street	F	265	846	455	251	171	86
20	Rose M Rd swale above Cemetery Rd	F	150	7	4	2	2	1
21	Buffalo Gulch - culvert at James Canyon Drive	G	251	139	89	57	43	25

Table 4-1. Summary of Peak Discharges at Key Locations

4.3 Identify Local Drainage Issues

4.3.1 Community Identified Drainage Problems

Input from the community and town officials provided sufficient information to identify many of the local drainage issues. The hydrologic modeling was used to support the community identified problems with discharge information. These drainage issues have been documented in a table format in Appendix H and are also presented on Drawing 2 of the Master Plan Maps in Appendix G.

4.3.2 Evaluation of Existing Drainage Facilities

Capacity of the existing drainage systems were evaluated at three locations – the 16th Street drainage system, the 12th and Mesa Street culvert, and the lower Main Street drainage system. Culvert crossings along James Canyon Drive were evaluated with the Boulder County/ AECOM road rehabilitation project and were not re-evaluated in this study.

4.3.2.1 16th Street Existing Storm Drainage System

The existing 16th Street storm drainage system consists of approximately 10 drainage pipes along with roadside drainage swales. Most pipe materials consist of corrugated metal pipe (CMP) with a few steel or ductile iron pipes (DIP). This network of pipes is fairly rudimentary with most inlet openings being a culvert projecting from the slope without flared end sections, trash racks, or other inlet improvements. There are four storm inlet structures with horizontal grates; however, besides these structures, there are no other junction structures and the remaining pipe junctions generally consist of two or more culverts projecting into an open sump in the ground. The effectiveness of this pipe system appears to be low as inlets and culvert openings seem to be partially or fully clogged at different locations and several locations appear that runoff may partially bypass the storm drain inlet.

The mainline of this system consists of 18" diameter CMP with the last pipe section being 24" steel or DIP. The outfall pipe projects out of stacked rock wall near the top of a 40-foot cliff. The rock wall, below the outlet pipe, appears to be in needs of maintenance. The capacity of this system is approximately 15-cfs which corresponds to a 25-year flow rate. Calculated flow rates at this location are 36-cfs (100-yr), 14-cfs (25-yr), and 11-cfs (10-yr).

4.3.2.2 12th and Mesa Streets Existing Inlet and Culvert

At 12th and Mesa Street a Type D inlet structure and 30" diameter concrete pipe have recently been constructed on the southwest corner of the intersection. The 30" pipe discharges into Gillespie Gulch alongside 12th Street. However, the Type D inlet appears to be constructed too high in elevation and the concentrated runoff flowing easterly along Mesa street appear to bypass the inlet. This inlet would have been better situated on the north side of Mesa Street where flows appear to go naturally.

The capacity of this system is approximately 60-cfs which is more than enough for the 100-year flow – if these flows were directed into the inlet. Calculated flow rates at this location, from Mesa Street, are 18-cfs (100-yr), 4-cfs (25-yr), and 3-cfs (10-yr).

4.3.2.3 Lower Main Street Existing Storm Drainage System

The existing Lower Main Street storm drainage system is located on the south side of Main Street, about 1,000-feet southeast of the intersection with James Canyon Drive. The storm system consists of two sections of 24" concrete drainage pipe along with two Type D inlets. The storm system discharges into a suitable drainage swale that outfalls into James Creek.

The capacity of this system is approximately 35-cfs which is more than enough for the 100-year discharge for flows currently draining to this inlet. This system has additional capacity to accept flows from 12th Street – provided they are properly directed to the storm drain inlets. Calculated flow rates at this location are 13-cfs (100-yr), 7-cfs (25-yr), and 5-cfs (10-yr).

4.4 Hydraulic Analysis of James Creek and Little James Creek

The hydraulic analyses of James and Little James Creeks were performed with the SRH-2D model (version 12.2) as implemented in the Aquaveo SMS software. This analysis considered stream inflows upstream of Jamestown and mapped approximate flood inundation limits for four streamflow frequencies: the 10-, 25-, 50-, and 100-year events. This analysis did not include inundation mapping for flows from local drainage basins that discharge into James and Little James Creeks in the proximity of the town.

Stream inflows were obtained from the 2016 LOMR Submission by AECOM. This is the proposed hydrology that was prepared by Jacobs for CDOT after the flood events of 2013.

Interval	James Creek Peak Flow Above Confluence (cfs)	Peak Flow Below Confluence (cfs)	Little James Creek at Confluence Peak Flow (cfs)
10-YR	776	912	423
25-YR	1278	1502	730
50-YR	1772	2095	1036
100-YR	2339	2777	1386

Table 4-2. James and Little James Creek FEMA Flowrates

This flood inundation mapping was based on the LiDAR topography that was obtained in November of 2016. The inundation maps can be found in Appendix E. It is important to note that the flood inundation maps in this report are not regulatory and are for information only.

The results of the flood inundation mapping show that the channel bank full capacity is just below a 10-year event. The model shows that flows begin to come out of the channel at the 10-year event (912 cfs) between 85 and 91 Main St., flowing down the road until rejoining the channel just west of the Main St. bridge.

Upstream of the confluence of James Creek and Little James Creek, the model shows that the flows exit the channel at the water plant beginning at the 25-year event (1278 cfs). At this flow rate, the flow travels down Ward St. until it meets the channel again at the Ward St. bridge.

As with any model, the 2-dimensional model used to analyze James and Little James Creek has limitations. The model assumes that no erosion occurs during a flood event. In reality, when a channel is exposed to high shear stresses such as those which occur in a flood event, material has the potential to move and the channel alignment can shift significantly.

4.5 Channel Erosion and Instability Analysis

The potential for lateral stream migration and vertical degradation was evaluated using the SRH-2D modeling results with the HEC-23 riprap revetment calculation. The results of this analysis show reach level bank instability would be expected to begin between the 25- and 50-year flow events (1502 cfs – 2095 cfs along James Creek, downstream of the confluence with Little James). There is some minor and localized bank potential instability at several locations for the 10-year flow event. At flow events more frequent than the 10-year event (i.e. the 2-year, 5-year), the channel appears to be relatively stable.

Upstream of the confluence in both James and Little James Creek, the analysis shows that reach level instability has the potential to occur at a 25-year event (1278 cfs for James Creek above confluence, 730 cfs for Little James Creek above confluence). At more frequent events including a 10-year event there are many localized areas that show the potential for instability.

The areas where the channel banks are unstable and channel degradation is expected to occur are presented on Figures 1-3 in Appendix F.

5.0 Recommended Drainage Solutions and Mitigation Measures

5.1 Debris Flow Mitigation

5.1.1 High-Tensile Ring Net Barriers

Lithos recommends the installation of debris flow nets, also referred to as flexible ring net barriers, in Drainages C, D, and F. Ring nets are comprised of interlocking high tensile steel wire rings that span the full width of a drainage channel. They are effective at capturing debris during a flow event under dynamic and static load conditions. Images of ring net examples are presented in Appendix B along with drawings that highlight the various net components. Water and fine sediment still can pass through the ring nets; therefore, the installation of adequate stormwater management infrastructure at the base of these drainage is highly recommended. Ring nets can be installed in parallel at different elevations along a drainage to increase the overall effectiveness and capacity of the ring nets. These multilevel barrier systems are designed to withstand overtopping forces without losing structural integrity. Once an upstream net reaches full capacity, additional debris will continue downstream to be captured in the next net, and so on.

Standard Geobrugg[™] VX/UX Flexible Debris Flow Protection Systems were used for sizing and cost estimate considerations for the three priority drainages. Geobrugg[™] debris flow VX systems consist of support ropes, brake rings, the ring net, border ropes, and abrasion protection. The UX systems are utilized for wider channels or higher loads and are comprised of the same components as the VX systems with the addition of support posts in the channel to increase the structural strength and maintain proper barrier height once filled.

The installation process for ring nets is dependent on the width of the net. Nets wider than 50 feet generally require the construction of reinforced concrete foundations for support posts installed in the channel bed and therefore require larger equipment to install. Nets less than 50 feet wide generally do not require support posts and are anchored to the channel flanks with wire rope anchors or flexible anchor heads. Spiral rope anchors or self-drilling anchors can be used to anchor into the native soil or rock. Flexible anchor heads allow loads not acting in line with the anchor to be transmitted in the pulling direction, therefore protecting the anchors from irreparable damage that would require replacement. The anchor length is based on measured rope forces and the bearing capacity of the soil or rock. Anchors are drilled into the soil or rock and concrete is used to reinforce the anchor point. Built-in brake rings dissipate impact energy to protect support ropes from overload through friction and plastic deformation.

Maintenance needs and the design life for ring net barriers depend on the magnitude and frequency of debris flows, as well as environmental conditions. The service life of the support ropes is exclusively dependent on the level of corrosion; therefore, corrosion protection can be applied to the ropes. Once loaded, individual rings should be replaced if they become severely deformed or fractured and the whole net should be replaced if several rings are deformed or fractured. Brake rings should be replaced when more than 50% of the maximum elongation has been reached. Stretching of the net due to elongation of the brake rings can be mitigated by re-tensioning the appropriate support ropes. Rope anchors must be replaced if they are pulled out of the ground by more than one inch.

Debris retained in ring net barriers remains in place until manually removed and the barriers are most effective at reducing damage downstream when they are empty of debris prior to a flow event. However, nets that have been previously filled with debris and not emptied, will still serve as check dams and will help to reduce the velocity of the debris flow, but will not be nearly as effective at keeping debris from reaching roadways or homes. Therefore, it is recommended that debris is removed from the ring nets following major flow events. Smaller retained material can remain in place; however, it should be a priority to maintain a clear basal opening between the bottom of the net and the channel in order to allow for efficient drainage during regular precipitation events.

The most effective method of debris removal will depend on equipment, accessibility, and debris type. It should be noted that the barrier systems are often under tension when impacted with debris and require special consideration when servicing the nets. Nets can be serviced from upstream and/or downstream, however downstream access requires crews to partially disassemble the support ropes or to sever rings to clear debris. Therefore, upstream maintenance is always preferred either manually or with an excavator to transport material off site. The effects of snow loading or avalanche forces should be accounted for in the final design and sizing of the ring nets. Accessibility, by foot, to barriers should be secured to allow for inspection of the support components at least twice annually, typically before and after winter. It is also recommended to regularly remove trees and shrubs from the channel to minimize potential for excessive blockage during smaller flow events.

5.1.2 Sizing Barrier Systems

All discussion of ring net sizing and capacities in this report should be regarded as preliminary estimates that require further analysis and final, location-specific design prior to the implementation of any of the recommended mitigation systems. Lithos utilized the DEBFLOW software provided by the ring net manufacturer Geobrugg[™] (DEBFLOW Software Manual, 2017) for their standard debris flow barrier systems in order to determine preliminary feasibility and sizing of ring nets for Drainages C, D, and F. The input parameters for the DEBFLOW software include debris flow parameters, channel geometry, and barrier geometry and spacing. For this report, all input parameters were estimated values. The channel geometry parameters were primarily based on the site investigation and aerial imagery, while debris flow properties were based on research and engineering experience. A detailed cross-section of the drainage channel at each proposed barrier location is required for design for a more accurate determination of sizing and retention volume.

The DEBFLOW software first determines whether a specific barrier system can withstand the estimated dynamic and static loads imposed on the ring net given the input parameters and then the software calculates a retention volume and global factor of safety for each barrier system. The software is able to perform analysis involving multilevel barriers as well. For example, the software estimated that a single VX barrier with the trapezoidal dimensions of 16-foot height, 13-foot base width, and 26-foot top width has a retention capacity of approximately 356 yd³ for granular material with a water content of 27 % and an upstream channel inclination of 24 degrees. The structural compatibility for this example was based on a debris flow surge of 2,030 yd³ and the barrier style was recommended to be a VX160-H6.

Estimating debris volumes prior to, or following an event is inherently difficult and dependent on variables such as seasonal precipitation, fire activity, sediment load and type, and elapsed time since the last event. Therefore, Lithos relied on the debris volume loss values calculated from Ayres' LiDAR comparison to size the barrier systems. Lithos aimed to size barrier systems with the estimated capacity to capture up to 50% of the debris volume loss experienced in Drainages C, D, and F between 2011 and

2016. The recommended barriers were also checked for structural compatibility in the DEBFLOW software using static and dynamic forces generated by the same 50% debris volumes. In a few cases, the barrier style had to be upsized in order to withstand the estimated dynamic forces generated by the debris flow on the ring net. Since the precipitation event in 2013 has been defined as a 500 to 1,000-year event, mitigation efforts designed to capture approximately half of that which is assumed to have primarily flowed in 2013 is reasonable for reducing future flow events within the design life of the barrier systems. In some cases, reaching 50% retention capacity could not be done for reasons discussed below. Table 5-1 provides details for the barrier systems recommended for Drainages C, D, and F based on outputs from the DEBFLOW software. A more complete table detailing proposed barrier system specifications is provided in Appendix C.

Drainage	Estimated Debris Volume Loss from 2013 Event (yd ³)	50% Debris Volume Loss (yd ³)	Barrier Capacity (yd ³)	Estimated System Retention Capacity (yd ³)
			356	
С	8,031	4,015	352	1,063
			356	
	16,220	8,110	1186	4,757
			1190	
U			1190	
			1190	
	4,852		721	
F		2,426	753	2,227
			753	

Table 5-1. DEBFLOW Output

The final design of the barrier systems for each drainage should consider utilizing portions on USFS land to increase the overall retention capacity. Through discussions with a USFS agent for Boulder County, the Team learned that installing ring nets on Forest Service land is only a minimal possibility at this time. As expected, the following would be required, at a minimum, prior to approval: permitting, construction and maintenance access plans, and an environmental impact study. The utilization of USFS land could be especially beneficial to increase the overall retention capacities in Drainages D and F.

5.1.2.1 Drainage C Barrier System – Net Barriers Sizing and Contamination Mitigation

Drainage C lost just over 8,000 yd³ of material between 2011 and 2016 and the base of the drainage, close to Overland Road, has been noted as a possible contamination source. White precipitation on the rock outcrop near Overland Road was observed during the site visit. The site visit revealed there was approximately 150 feet of drainage that appear to have viable conditions for installation of ring nets. The viable section started approximately 50 feet up the drainage from the road and continued to a distance of 200 feet from the road. At approximately 250 feet, the channel narrows significantly, to no more than two feet wide. The channel is relatively steep through the viable section with an average grade of about 40%. The installation of at least three barriers is recommended in this drainage, the

quantity and spacing of which is limited by the relatively short viable section due to the channel geometry. The VX160-H6 barrier, or an equivalent product, is recommended for all three proposed locations shown Figure 5-1. The installation of three ring net barriers at the recommended locations is estimated to provide up to 1,060 yd³ of debris retention capacity. The goal of retaining up to 50% of the 2013 debris volume was determined to be unfeasible due to the aforementioned channel constraints. Mitigation for the possible contamination source associated with this drainage is also recommended.

5.1.2.2 Drainage D Barrier System – Net Barriers Sizing, Headwall, and Detention Basin

Drainage D lost just over 16,000 yd³ of material between 2011 and 2016 and was a major contributor of damage to and sediment deposited on Overland Road and in Little James Creek during the 2013 flooding. The drainage is scoured to bedrock through most of the channel with well-defined natural levees visible along the 200 feet closest to Overland Road. The channel does not appear to have viable conditions for installation of ring net barriers until approximately 300 feet upstream from Overland Road but then remains viable all the way upstream to the flow initiation area. The drainage is located on USFS land for the first 315 feet from Overland Road, and then re-enters USFS land approximately 950 feet upstream from the road as shown in Figure 5-1. Lithos recommends the installation of at least four UX180-H6 ring net barriers, or an equivalent product, on the portion of the drainage that is not on USFS land. The combined capacity of the four barriers proposed for Drainage D is estimated at approximately 4,750 yd³. As mentioned previously, the UX style barriers utilize foundations for support posts in the drainage channel and therefore the construction process and required equipment will likely be different than for the other drainages. The UX barrier style was required in order to withstand the estimated dynamic loads.

In addition to the ring net barriers, Lithos recommends the construction of a detention basin and headwall at the base of the drainage to further protect Overland Road and Little James Creek from residual debris not retained in the ring nets. There is already a 36-inch corrugated metal pipe and concrete headwall proposed for construction at the base of Drainage D in the ROW adjacent to Overland Road. However, Lithos proposes an approximately 15-foot-high concrete headwall with the top of the headwall and associated wing walls tying into the existing slope at approximately 7,150 feet of elevation. The wall would be approximately 25 feet wide. The location of the headwall would have to be set back from the road approximately 75 feet, which would put it outside of the current ROW and onto USFS land. The drainage widens significantly at the road so the proposed headwall would need to be positioned further upstream at a narrower point in the drainage where the headwall can effectively tie into the existing topography. The proposed headwall and detention basin is delineated in Figure 5-1.

Alternatively, Lithos considered utilizing additional ring net barriers further upstream from the four already proposed to increase the overall debris retention capacity. However, the additional ring nets would be located at higher elevations on USFS land where equipment access for installation and maintenance would be significantly more difficult. Therefore, the detention basin and headwall option is more feasible than the additional ring nets for the sake of increasing retention capacity and maintenance accessibility. Performing regular maintenance of the detention basin and headwall is needed to improve drainage by keeping the basin clear of debris and the outlet structure clear of vegetation and debris.

5.1.2.3 Drainage F Barrier System

Drainage F, also known as Howlett's Gulch, lost just over 4,800 yd³ of material between 2011 and 2016 and claimed the life of a Jamestown resident during the 2013 debris flows. Based on field observation, the drainage has viable conditions for ring net installation starting approximately 100 feet from the road where the channel steepens and the viable conditions continue all the way upstream to the flow initiation area. The channel is scoured to bedrock through the majority of the drainage. Sparse vegetation and loose soil, some of which may be historic mine tailings, were observed on the channel flanks. The drainage exits Jamestown limits and intersect USFS land approximately 430 feet upstream from the road, as shown in Figure 5-1.

Lithos recommends the installation of at least three VX160-H6 ring net barriers, or an equivalent product, in the portion of the drainage that is not on USFS land, between 100 feet and 430 feet from the road. The combined retention capacity of the three proposed barriers is estimated at approximately 2,200 yd³ of debris, which is just less than the 50% 2013 debris volume. If feasible, installing a fourth barrier 600 feet upstream from the road on USFS land will add additional protection. A fourth barrier is estimated to increase the overall retention capacity by 750 yd³ in the drainage and provide a barrier positioned closer to the flow initiation zone source on Porphyry Mountain. The fourth recommended barrier was not included in the cost estimates discussed in Section 6.0.



5.1.3 Additional Risk Reduction Methods

In addition to the installation of ring net barriers and a headwall, there are numerous non-construction efforts that can be implemented in the area to further reduce the risk of damage and personal injury from debris flows.

5.1.3.1 Early Warning System

Short duration and high intensity rainfall is often a trigger for debris flows, therefore, timely notification to the public of such conditions is very important. Lithos recommends the implementation of an early warning system similar to that which was installed along I-70 following the 1994 Storm King debris flows. The Town is currently in the process of installing a rain gauge system. Additional instruments that can be helpful for early detection of potential hazards include stream gauges and soil saturation sensors. Providing pertinent data to local safety officials so there can be swift enforcement of the appropriate precautions to reduce risk of personal injury to Town residents is important. Emergency alerts via reverse 911 and/or warning sirens have also proven to be effective and is recommended for the Town, if it is not already implemented.

5.1.3.2 Signage and Education

Additional risk mitigation options include the installation of increased signage along the road through town that identify the debris flow-prone areas to travelers. Signage can also be set up to flash when the monitoring systems indicate conditions are favorable for debris flows or other hazards. Reasonable land acquisition by the Town of properties damaged in the September 2013 event is also recommended to limit development and avoid future damage in high-risk areas. Lithos supports Boulder County's HMP which recommends incentivizing mitigation efforts on private property through education, land acquisition, elevation relocation programs, and community wildfire protection plans. The HIRA report recommendations to establish a Town auxiliary for Fire and EMS emergency services is also recommended.

Continued community education and involvement is very important as conditions evolve and new mitigation efforts are implemented. Prior to storms, the United States Geological Survey (USGS) recommends residents familiarize themselves with surrounding terrain, learn the history of previous failure areas, support local building ordinances, look for signs of movement or tilting trees, and contact local authorities to learn about emergency response and evacuation plans. During storms, the USGS recommends residents stay awake and alert, listen to weather updates on the radio, listen for unusual sounds that could indicate moving ground, be alert while or avoid driving during storms as slopes can quickly become unstable, and consider leaving the area ahead of a heavy storm.

5.2 Local Drainage Solutions

The nature of the majority of drainage problems in Jamestown is a lack of a formal conveyance system. This generally results in localized flooding of roadways and structures, and erosion issues. The following subsections describe the solutions recommended for the various issues that were relayed to the master plan team.

In general, the focus of the solutions presented here are to collect concentrated flows into a formal drainage system (whether piped or surface) and convey these flows to James Creek. These solutions will

in general solve multiple issues such as conveyance, local flooding, erosion, infrastructure damage, and transportation impediments. Low Impact Development (LID) solutions were considered and applied where and when feasible during project development. A LID solution was proposed at one of the project locations. In many cases, individual components of each project could be constructed independently, allowing the improvements to be built in phases or as opportunity arises.

The project identified with for 30% design is Project C2 - which consists of improvements along Andersen Hill,16th Street, and Mesa Street. This conceptual design is presented on the 30% Plan Set in Appendix I.

5.2.1 Project A. Main Street Conveyance – Ward St. to Howlett's Gulch

Project A consists of surface drainage improvements along Main Street between Ward Street and Howlett's Gulch as well as a small water quality feature between Main Street and James Creek. The drainage problems in this area are primarily due to lack of conveyance for runoff which flows along James Canyon Drive. These flows cause local flooding issues and erosion. Collecting these flows in a formal drainage system and directing them to the creek in a non-erosive manner will solve both water quality issues, transportation impediments, and roadway deterioration. Components of this project would include:

- Flared End Sections with Trash Racks Install a flared end section with trash rack onto each of the two 18-inch roadway culverts along James Canyon Drive immediately upstream of the Ward Street intersection. These culvert entrances need routine and frequent debris removal maintenance to assure they remain open for future rainfall events.
- Drainage Swales
 - Construct a roadside drainage swale south of Main Street and just east of Ward Street. This swale may outfall directly to the creek or discharge into a proposed water quality facility.
 - Construct a roadside drainage swale on the north side of Main Street which outfalls into Howlett's Gulch.
- **Concrete Drainage Cross Pan** Construct a concrete drainage cross pan across Main Street, approximately 140-feet east of Ward Street. This pan will convey flows from the north side of Main Street towards James Creek and the proposed water quality facility.
- Water Quality Facility Between Main Street and James Creek a passive water quality facility may be installed to filter sediment from runoff. This would consist of a concrete sediment forebay followed by a vegetated filter strip. The forebay would collect the majority of heavy sediments and require frequent maintenance.

The elements of this proposed project are displayed on Drawing 3 (Project A) in Appendix G.

5.2.2 Project B1. Town Hall/ Mercantile Drainage Pipe System

The purpose of Project B1 is to convey flows from behind Town Hall safely and efficiently to James Creek. Approximately 8 acres of hillslope drain to this location behind Town Hall. Currently these flows surface drain between Town Hall and the Mercantile. The existing drainage crosspan at Main Street is shallow and is in poor condition. It is likely that flows will split directions at Main Street and flow both towards James Creek in the existing concrete drainage swale and easterly along Main Street. It is recommended that an improved drainage system be installed in this location. This improvement could consist of either a piped drainage system (Project B1) or simply an improved drainage cross pan at Main Street (Project B2). Project B1 would consist of the following items:

- **24"** Storm Drainage Pipe Install 24" concrete storm drainage pipe beginning at the low point behind Town Hall and extending to James Creek.
- Storm Drainage Collection Inlets Install 3 storm drainage collection inlets as follows:
 - 1) CDOT Type D inlet behind Town Hall.
 - 2) CDOT Type C inlet adjacent to Main Street between Town Hall and the Mercantile.
 - 3) CDOT Type R inlet along the south curb line of Main Street.
- **Drainage Diversion Berm** A 2-foot tall drain diversion berm may be necessary behind Town Hall protect the existing structures from hill slope drainage.

The elements of this proposed project are displayed on Drawing 4 (Project B) in Appendix G.

5.2.3 Project B2. Main Street Drainage Cross Plan - Town Hall/ Mercantile

An alternate to project B1 is to simply preserve the existing surface drainage system and replace the failing drainage cross pan in Main Street. It is recommended that the replacement pan be larger in width and deeper so that frequent flows are adequately directed toward the existing concrete swale and James Creek.

The elements of this proposed project are displayed on Drawing 4 (Project B) in Appendix G.

5.2.4 Project C1. Andersen Hill Street Erosion Protection

Project C1 will reduce the erosion issues along the Andersen Hill Street drainage swale. Currently flows that are not collected by the existing storm inlets on 16th Street and runoff from the hill slope are intercepted by Andersen Hill Street and conveyed along the hill-side flowline of the road. This appears to be causing frequent erosion and creates an additional obstacle for drivers to negotiate. Implementation of the following items will significantly reduce the amount of erosion in this location.

- **Riprap Swale Lining** Excavate the existing swale and rock erosion protection. Install gravel bedding followed by 6-inch riprap (1-foot thickness). The final swale configuration should leave 6- to 12-inches of flow depth below the edge of roadway.
- Rock Check Structures In addition to the riprap swale lining, rock check structures can be installed every 10 to 20-feet in the swale. These rock check structures are miniature dams that created ponding and slow the velocity of concentrated flows. It is recommended that 9-inch riprap be used for these check structures. A detail for these rock checks is provided at the end of Appendix I.

The elements of this proposed project are displayed on Drawing 5 (Project C1) in Appendix G and in the 30% Design Drawings in Appendix I. In addition to the C1 erosion protection project, implementation of Project C2 or C3 will improve the collection of storm water runoff along 16th Street which will also help reduce the erosion problem along Andersen Hill Street.

5.2.5 Project C2. 16th Street Storm System Replacement

Project C2 includes full replacement of the existing 16th Street storm drain system with an improved system. The existing system consists of a loose network of 18" CMP pipes which are very shallow and generally not joined with a drainage structure at junctions. The existing system appears to intercept some of the stormwater drainage, but appears to have clogging problems at inlet and culvert openings, water bypass problems, pipe freezing problems, and systemic erosions issues. In addition, the school roof downspouts mostly discharge onto the road. Last, the outfall pipe of this system projects from a 45-foot cliff over James Creek and the historic rock wall below this outlet pipe appears to be in need of maintenance.

In general, the drainage problem in this area of Jamestown is that the slopes are very steep and the drainage system does a mediocre job at collecting drainage. Flows that bypass inlets or culverts cause significant erosion on all of the gravel roads and most acutely on Andersen Hill Street. Collecting these flows in a formal drainage system will solve erosion issues, water quality issues, transportation impediments, and roadway deterioration. Components of this project would include:

- Storm Drainage Inlet Structures Installation of 8 storm drainage inlet structures as identified on the Project C2 drawing (sheet 6 of the Master Plan Maps) and on the 30% design plans. This includes (5) Type 13 valley grate inlets; (1) Type C inlet; and (2) Type D inlets. These inlet structures should be adequately sumped (depressed) to encourage runoff to collect at the inlet location and constructed with concrete aprons which helps with maintenance and erosion. It is important that these inlet grates be cleaned after large storm events, or at minimum several times per year. Example pictures of these inlet types are provided at the end of the 30% design plan set.
- Flared End Sections with Trash Rack The upstream end of the drainage system on 16th Street should include flared end sections (FES) appropriately placed in the bottom of the roadside swales. These FESs should have adequate or oversized trash racks to prevent clogging of the drainage pipe. It is important that accumulated debris on these end sections be removed after large storm events, or at minimum several times per year.
- **18" Reinforced Concrete Pipe (RCP)** Installation of approximately 750-feet of 18" RCP pipe as shown on the 30% design plans.
- **Riprap Erosion Protection** Riprap erosion protection will be needed at two locations where the slopes approaching the inlet structures are excessively steep. These locations are depicted on the Project C2 map in Appendix G and on the 30% design plans in Appendix I.
- **Concrete Cross Pan** At the corner of Andersen Hill and 16th Streets, drainage flows appear to partially bypass the existing storm drainage inlet structure. Although this project proposed to replace this inlet, the surface flows in this location have the potential to bypass a future inlet if a drainage diversion structure is not installed. It is recommended that a large concrete drainage cross pan be installed at this corner, intercepting surface flows and directing them into the drainage inlet.
- **Relocation of Roof Down Spouts at School** The majority of the school roof downspouts, on the north side of the building discharge directly onto Mesa Street. It appears that this contributes to surface erosion and winter icing. It is recommended that these downspouts be combined in a manifold collector pipe and discharge directly onto the new storm drain inlet in this location.

• **Grout Rock Wall** – The existing rock wall below the storm outfall pipe in the side of Andersen Hill appeared to be deteriorating. This rock wall should be repaired with high strength, nonshrink grout. It is recognized that this will be a difficult operation to perform as the rock wall is on the side of 45-foot tall cliff and does not have access from the base of the wall. Professional contractors should be consulted to discuss the best means and methods for this repair.

The elements of this proposed project are displayed on Drawing 6 (Project C2) in Appendix G and on the 30% Design Plans in Appendix I.

5.2.6 Project C3. 16th Street Storm System Rehabilitation

As an alternative to full replacement of the 16th Street storm drain system, the existing system could be rehabilitated and improved with Project C3. The main focus of this project is to improve the drainage conditions at all of the inlet and culvert locations to reduce the amount of bypass flows. This project will reuse the existing CMP drainage pipes as much as possible. Components of this project would include:

- **15" PVC Pipe** Replace the existing 8" PVC pipe along Mesa Street by the school with 15" PVC pipe. The new pipe should be installed as deep as possible at with as much slope as possible.
- Inlet Replacement At minimum, two of the existing inlets should be replaced with larger Type 13 inlet structures, as shown on the Project C3 map in Appendix G. It is important that the inlet grates are cleaned after every major storm event or at minimum several times per year.
- Flared End Sections with Trash Rack The upstream end of the drainage system on 16th Street should include flared end sections (FES) appropriately placed in the bottom of the roadside swales. These FESs should have adequate or oversized trash racks to prevent clogging of the drainage pipe. It is important that accumulated debris on these end sections be removed after large storm events, or at minimum several times per year.
- **Riprap Erosion Protection** Riprap erosion protection will be needed in at least three locations where the slopes approaching the inlet structures are excessively steep. These locations are depicted on the Project C3 map in Appendix G.
- **Concrete Cross Pan** At the corner of Andersen Hill and 16th Streets, drainage flows appear to partially bypass the existing storm drainage inlet structure. A large concrete drainage cross pan should be installed at this corner, intercepting surface flows and directing them into the drainage inlet.
- **Relocation of Roof Down Spouts at School** The majority of the school roof downspouts, on the north side of the building discharge directly onto Mesa Street. It appears that this contributes to surface erosion and winter icing. It is recommended that these downspouts be combined in a manifold collector pipe and discharge directly onto the new storm drain inlet in this location.
- **Grout Rock Wall** The existing rock wall below the storm outfall pipe in the side of Andersen Hill appeared to be deteriorating. This rock wall should be repaired with high strength, nonshrink grout. It is recognized that this will be a difficult operation to perform as the rock wall is on the side of 45-foot tall cliff and does not have access from the base of the wall. Professional contractors should be consulted to discuss the best means and methods for this repair.

The elements of this proposed project are displayed on Drawing 7 (Project C3) in Appendix G.

5.2.7 Project D. James Canyon Rd Drainage – High St. to 15th St.

The purpose of Project D is to reduce erosion along High Street and James Canyon Drive near the Fire Department Station and east from this location. A significant amount of runoff discharges from the Skunk Tunnel watershed basically straight down High Street. These flows cause erosion in front of the Fire Department Station and along the driveways to the east. These problems may be significantly reduced with the installation of Project D, described as follows:

- **Erosion Geo-Grid** Install a high strength geo-grid in the High Street roadway for approximately 250-feet uphill from James Canyon Drive. This will stabilize the subgrade of the roadway and prevent severe washouts during high flow events.
- **24"** Storm Drainage Pipe Install a 24" concrete storm drainage pipe beginning at the corner of the Fire Station driveway and High Street. This pipe system should extend to the east approximately 150-feet before discharging into a proposed swale.
- Storm Drainage Collection Inlets Install 2 storm drainage collection inlets as follows:
 - 1) CDOT Type D inlet at the bottom of High Street.
 - 2) CDOT Type C inlet just east of the Fire Station driveway.
- **Storm Drainage Swale** Construct a 2-foot deep by 21' wide drainage swale from the end of the 24" pipe, proceeding along James Canyon Drive, until 15th Street.
- Rolling Dip Crossing or 18" Culvert At 15th Street, just north of James Canyon Drive, a crossing needs to be created to convey the flows in the proposed swale across 15th Street. This could be a "rolling dip" style crossing or an 18-inch concrete culvert.

It should be noted that the low flows at this location will be conveyed to James Creek via the existing 18" concrete culvert which is just east of 15th Street. This culvert has approximately a 2-year flow capacity. Flows greater than this will continue east a little further and overtop James Canyon Drive.

The elements of this proposed project are displayed on Drawing 8 (Project D) in Appendix G.

5.2.8 Project E. Lower Main Street Grading – East of James Creek

Project E proposes to regrade the roadway of Lower Main Street, east of James Creek, to increase its ability to intercept surface runoff. Recently two Type D inlets have been installed with a storm pipe system along the south flowline of Main Street. However, the surface drainage swale on the south side of the street is shallow and the road crown is not high enough to adequately intercept flows. Improving the road grading by raising the road crown along this section of road will increase the effectiveness of the storm drain system. Components of this project include:

- **Regrade Road** Regrade the lower Main Street roadway to provide a higher road crown and a drainage swale on the inslope side of the road.
- **Outlet Swale Grading** Regrade the outlet swale to James Creek to eliminate ponding and provide positive drainage all the way to the creek.

The elements of this proposed project are displayed on Drawing 9 (Project E) in Appendix G.

5.2.9 Project F. 12th Street Grading and Swale – Mesa to Main Street.

Project F will improve the drainage situation and reduce erosion along 12th Street, between Mesa and Main Streets. There is an existing Type D inlet at the southwest corner of Mesa and 12th Street. Unfortunately, this inlet has been constructed too high in elevation to intercept most flows, and as a result most runoff goes to the north side of Mesa Street and is eroding both Mesa and 12th Streets. In addition, the proposed Gillespie Gulch improvements, soon to be constructed, do not include drainage storm drainage structures to intercept and convey the local runoff to Gillespie Gulch. As a result, the best solution at this location is to construct two drainage swales described as follows:

- Mesa Street Drainage Swale The Gillespie Gulch improvements proposed to construct a drainage swale along the south side of Mesa Street. This swale needs to be constructed so that flows are directed into the existing Type D inlet. This swale will be difficult to maintain and a riprap lining with rock checks may be necessary to keep the swale in place.
- **12th Street to Main Street Drainage Swale** The Gillespie Gulch improvements also propose to construct a drainage swale on the west side of 12th Street, discharging westerly to the south flowline of Main Street. This swale needs to be extended, in conjunction with Project E, to the existing inlets on the south side of Main Street. Erosion protection may be necessary along the 12th Street section of this swale.

The elements of this proposed project are displayed on Drawing 10 (Project F) in Appendix G.

5.2.10 Project G. Buffalo Gulch Outfall and Culvert

The existing 24" RCP culvert crossing James Canyon Drive at the outfall of Buffalo Gulch is sufficiently sized to convey the 10-year storm flows from this watershed. However, the inlet condition to this culvert is poor and appears to frequently clog. In addition, the outfall swale, between James Canyon Drive and James Creek was not constructed with an impermeable liner as previously proposed. The owner of the residential structure, just east of this location, reports that the ground water levels have become higher than normal at the structure. It is suspected that flows in this swale may be increasing the ground water levels. Further geotechnical and ground water analysis is recommended to more precisely determine the causes and solutions of this problem. Project G proposes two solutions that may help with this drainage situation, including:

- Flared End Section with Trash Rack The upstream end of the culvert should have a flared end sections (FES) with an oversized trash racks installed. It is important that accumulated debris on this culvert entrance be removed after large storm events, or at minimum several times per year.
- **Swale Lining** The existing swale may be relined with a high quality impermeable geotextile. This will include removal and reinstallation of the existing swale riprap.

The elements of this proposed project are displayed on Drawing 11 (Project G) in Appendix G.

5.2.11 Project H. Spruce Street Grading

Spruce Street, east of 16th Street, has a low point that frequently ponds storm water. The solution for this problem is to regrade the roadway towards the outslope to remove the depression. A concrete sill at the edge of the road would help preserve the road grade. A culvert installation would be another option. The elements of this proposed project are displayed on Drawing 12 (Project H) in Appendix G.

5.2.12 Project I. Debris Flow and Water Quality Issues Along Little James Creek.

Project I, shown on Drawing 13 in Appendix G, depicts the location of the Debris Flow Project D. This project is part of the debris flow recommendations in this study. This map was included to add additional detail about the location of the proposed retaining wall for the debris basin.

5.3 Creek Analysis Recommendations

Based on the analysis that was performed, a summary of potential results from the 4 frequencies of flood events analyzed (10-, 25-, 50-, and 100-year) has been tabulated below. These flow rates have been correlated to the existing stream gage located on the Main St. bridge. Current flow data for this stream gage can be found at UDFCD.OneRain.com.

Recurrence Interval	Depth at Main St. Gage (ft)	Flowrate (cfs)**	Potential Areas of Flooding	Potential Areas of Erosion
10-YR	2.3*	912	Downstream of 91 Main St.	Localized erosion in James Creek downstream of confluence (near Fire Dept., Porphyry Gulch, and Hill Gulch), many spots upstream of confluence.
25-YR	3.5	1,502	Water Plant/Ward St. and increased flooding downstream of 91 Main St.	Most areas upstream of confluence, increased erosion in James Creek downstream near Town Hall, Porphyry Gulch, and Hill Gulch.
50-YR	4.4*	2,095	Main St. at Cemetery Rd.	Reach level instability up and
100-YR	5.3*	2,777	Increased flooding around Ward St.	downstream of confluence.

Table 5-2. James and Little James Creek Flooding and Erosion Summary

*Depth was interpolated from existing stage discharge curve of stream gage

**Flowrates are for James Creek downstream of confluence

As seen in Table 5-2, the channel will exceed its banks beginning at a 10-year flow. At a 10-year event, flooding is isolated to the area between 91-85 Main St. where it extends to the street, flowing east until it rejoins the channel at the Main St. bridge. At a 25-year flow, water exceeds its banks upstream of the confluence on James Creek at the water plant. At a 50-year flow, flooding is observed on the south side of the creek at Main St. and Cemetery Rd. At a 100-yr flow, the channel comes out of bank across from Town Hall as well as increased flooding at all the previously mentioned areas.

Potential erosion issues begin to surface at the 10-year event with some localized areas of erosion downstream of the confluence with many spots upstream of the confluence on both James and Little James Creek also being prone to erosion. At 25-year flows, the majority of both channels upstream of the confluence are likely to begin to erode with increased erosion downstream of the confluence. At 50-year flows and above, reach level instability is likely to be observed.

Because James Creek has recently undergone significant man-made changes, it can be expected that natural changes will be seen in the coming years. The creek will naturally transport material from areas of high shear stress as it finds a "new normal" condition. A good practice would be to walk the entire reach at least once a year and especially after high flow events, documenting and photographing any changes that are seen. Special attention should be given to the drop structures, watching for erosion on the outer ends where it ties into the bank. If the boulders keyed into the bank become exposed, this could lead to the failure of the entire structure and rapid bank erosion.

On Little James Creek, it will be important to maintain capacity in all culverts. These should be maintained on a regular basis, clearing out debris and sediment build up as these will decrease the culvert's capacity to transport flow and could lead to a clogged condition, causing overtopping and possibly road/bridge failure. This applies to all culverts and inlets, but especially those in the main channels.

To maintain awareness of flow conditions in James Creek it is recommended that a visual flow gage be installed in a highly visible location. A good location for this is on bedrock along the creek across from Town Hall and The Mercantile, near the Town Square. See Figure 5-2 for recommended location. Placement at this common gathering space will maximize usefulness of the gage.



Figure 5-2. Recommended Creek Gage Location

6.0 Opinion of Probable Construction Costs

The following opinions of probable mitigation cost (cost opinions) presented herein include consideration for ring net and headwall materials, labor costs, and contingency for difficult site access, difficult site conditions, and permitting or easements. A Geobrugg[™] representative provided materials cost estimates for the ring nets and provided insight regarding installation costs and requirements. Detention basin and headwall cost estimates were based on anticipated material, labor, and site preparation requirements. The cost estimates and corresponding assumptions are presented below in Table 6-1. A more complete cost estimate is presented in Appendix D. Cost estimates are based on 2017 dollars and do not include final design costs or future maintenance costs since they are primarily dependent on site access and the frequency and magnitude of debris flows over the course of the barrier's life.

Project Name/Location	Estimated System Retention Capacity (yd ³)	Barrier Style	No. of Barriers	Estimated Cost
Drainage C	1,063	VX160-H6	3	\$514,800
Drainage D	4,757	UX180-H6	4	\$1,063,920
Drainage D	670	Detention Basin & Concrete Headwall	1	\$315,000
Drainage F	2,227	VX160-H6	3	\$514,800

Table 6-1. Opinion of Probable Construction Costs: Debris Flow Projects

Table 6-2 presents our opinion of probable project costs for the conceptual drainage projects. The construction cost estimates include mobilization, labor, materials, traffic control, erosion control, and contingency. They do not include engineering/final design, administration, permitting, construction management, land acquisition, or future maintenance costs. Maintenance needs are described for each project, but a dollar value has not been calculated for maintaining each project. Details for the local drainage projects cost estimate can be found in Appendix J.

Project Name	Project Location	Description	Estimated Cost		
Α	Main St. & Howlett's Gulch	Swale, filter strip, and inlet grading	\$53,200		
B1	Main St. & Town Hall	New storm pipe and inlets	\$81,900		
B2	Main St. & Town Hall	Replace cross pan	\$8,400		
C1	Andersen Hill Road	Erosion Protection	\$39,900		
C2	16 th Street	Replace storm system	\$270,100		
C3	16 th Street	Storm Sewer Rehabilitation	\$67,800		
D	High St. to 15 th Street	Erosion protection and storm drainage	\$85,400		
E	Main St. E. of Creek	Regrade road	\$15,700		
F	Gillespie Gulch	Regrade Road, extend swale	\$10,900		
G	2199 James Canyon Dr.	Line channel, improve inlet	\$10,400		
Н	Spruce St.	Regrade Road	\$7,000		

Table 6-2. Opinion of Probable Construction Costs: Local Drainage Projects

7.0 Stormwater Management

7.1 Stormwater Quality and Management Strategies

Stormwater quality management strategies for Jamestown should be focused around erosion prevention and conveyance of stormwater in proper drainage systems. It appears that the largest water quality issue in Jamestown is high sediment loading from local erosion due to steep slopes, concentrated flows and lack of formal or adequate drainage systems. Fertilizer washoff, nutrient loading, and oils and greases do not appear to be major sources of pollution in this community. The primary challenges here are the steep slopes, lack of space for larger stormwater facilities, and lack of formal drainage systems. Conventional "end of pipe" water quality treatment methods, such as extended detention water quality ponds (sedimentation ponds), are not feasible here due to the steep slopes and lack of space.

On the other hand, Low Impact Development (LID) methods do not require large amounts of space and can fit in smaller areas throughout a drainage network. However, LID strategies which are primarily filtration based, such as permeable paving, rain gardens, and bio-retention, do not work well in high sediment loading situations. These Best Management Practices (BMPs) tend to clog easily when sediment inflow amounts are high. As such, their applicability and successfulness in Jamestown would be limited and they would require frequent maintenance. LID strategies that are straining based, such as grasses swales and grassed filters or buffers, may work well in Jamestown. The main maintenance needs for these facilities are mowing (as necessary), trash and debris removal, and occasional sediment removal. Long term maintenance for grassed swales or buffers which have filled-in with sediment would include removal of excess sediment, regrading, and revegetation.

In addition to pollutant removal, recent stormwater management approaches have also began to include "hydromodification" schemes. The purpose of hydromodification is to restore natural flow regimes to the receiving waterbodies. However, the modest increases of imperviousness in Jamestown due to buildings, roads, and paving are relatively small on the watershed level and likely do not present significant changes to the hydrologic flow regimes of James Creek. As such, hydromodification techniques of LID or conventional over-detention strategies are not meaningful for the overall hydrology of James Creek.

Recommended strategies to reduce erosion and improve stormwater quality for Jamestown include:

- Collect concentrated flows in appropriate and adequate storm drainage pipes or surface swales. (Eliminate the water sources of erosion before erosion occurs.)
- Install riprap erosion protection in areas of frequent erosion.
- Grassed swales.
- Grassed filter or buffer strips.
- For swales with erosion problems, consider riprap linings and rock checks. If this is not sufficient, a concrete swale or piped drainage system may be necessary.
- Re-vegetate barren areas and maintain healthy vegetation around surface swales.
- Consider Low Impact Development (LID) strategies that are applicable (i.e. straining based BMPs: grassed swales, and grassed filters/buffers).
- Install concrete sediment forebays where possible.
- Street sweeping (James Canyon Drive) and storm drain pipe cleaning (jet-vacing) are BMPs that may be practical for Jamestown.

• Promote pollution prevention (illegal dumping and discharges) and "good house keeping" methods, such as covering outdoor storage and chemical storage areas.

8.0 Evaluation and Recommendations for Town Policy

8.1 Existing Town Ordinances/Policies

8.1.1 Ordinance Review

The following ordinances have been reviewed from a stormwater, drainage, and debris flow perspective.

Ordinance No. 3, Series 1994 – AN ORDINANCE PROVIDING FOR ROAD PERMITS AND STANDARDS AND REQUIREMENTS RELATING THERETO

Review:

The road standards ordinance addresses cut and fill slopes, erosion control practices and structures (i.e. ditches, culverts, revegetating), compaction requirements, protection of existing infrastructure and property (including water mains). It addresses allowable road width and grade and allows for roads to be "ditched, insloped or flat as determined by the town engineer based on soil conditions and gradient."

Recommendations:

Due to the high erosion potential throughout town, the following recommendations are offered.

- Consider adding language requiring existing drainage flow patterns to be addressed.
- Do not allow flat cross slopes on roadways. Require roadways to be insloped, crowned or outsloped with drainage addressed with ditches, culverts, inlets, etc.

Ordinance No. 7, Series 2004 – AN ORDINANCE PROVIDING FOR THE ADOPTION OF DRIVEWAY, AND EMERGENCY ACCESS STANDARDS FOR THE TOWN OF JAMESTOWN

Review:

The ordinance addresses construction of private roadways and driveways. It includes erosion control requirements and considers drainage impacts. A variance process is identified to address terrain constraints.

Recommendations:

Due to the high erosion potential throughout town, the following recommendation is offered.

• Consider adding language to disallow flat cross slopes on private roadways to reduce erosion potential, pothole formation, and other maintenance issues exacerbated by poorly graded roadways. Roads should be insloped, crowned or outsloped and should address drainage with ditches, culverts, inlets, etc.

Ordinance No. 2, Series 2009 – AN ORDINANCE ADOPTING REVISED SUBDIVISION REGULATIONS AND PROVIDING FOR THE ENFORCEMENT THEREOF

Review:

The ordinance addresses erosion control, revegetation, and drainage for the Preliminary Plan in section

7.2(g.) and addresses the floodplain in section 7.2(h.). The ordinance addresses public improvements to be given to the Town during the subdivision process in Section 10, Subdivision Agreement. Design standards for steep terrain, drainage, floodplain and the natural environment in the Preliminary and Final Plat Plan are addressed in Section 11.

Recommendations:

Currently, the Town does not have many regulations addressing private property site design. Although locating structures in hazard areas is discouraged, the Town could consider more regulatory standards to help guide development away from drainages and potential stormwater management areas. For example, required setbacks along creeks and drainages for new buildings and driveways, or requiring permanent stormwater quality best management practices for all new development or substantial redevelopment.

Ordinance No. 4, Series 2011 – AN ORDINANCE CONCERNING THE TOWN WATERWORKS AND WATERSHED

Review:

The ordinance is meant to protect the Town's water supply from pollution or from activities that will create hazard to health and water quality. It requires a permit from the Town, or written notification to the Town, for certain activities within the watershed district located upstream from the Town's water treatment plant. Protection measures for the ordinance are based on the Town's 2011 Source Water Protection Plan.

Recommendations:

No changes or additions. This ordinance has a broad scope of authority if needed to address various issues in the tributary watershed that may or may not be directly related to mining impacts or National Forest uses.

Ordinance No. 8, Series 2012 – AN ORDINANCE PROVIDING FOR THE PREVENTION OF FLOOD DAMAGE THROUGH ADOPTION OF PRINCIPLES PROMULGATED BY THE FEDERAL EMERGENCY MANAGEMENT AGENCY

Review:

This ordinance sets baseline standards for new development or substantial improvements within the regulatory floodplain in an attempt to avoid property damage, bodily injury, and loss of life in areas prone to riverine flooding up to and including the 1% or 100-year flood event. This ordinance provides a comprehensive list of definitions, standards and best practices for local floodplain administration. Operating within these guidelines may provide better flood insurance rates for the community. However, the role of Floodplain Administrator requires a certain level of technical knowledge and experience to manage floodplain impacts. The national standard for Floodplain Administrators is the "Certified Floodplain Manager" certification, or CFM. Bi-annual continuing education is required to maintain the CFM certification.

Recommendation:

No changes or additions to the ordinance. There are several follow up items for the Town to consider and take action on:

• Continue to designate a local Floodplain Administrator with the necessary training and experience. This may be more cost effective with a contract review position.

- Provide floodplain review and enforcement as a regular part of the building permit and engineering review process for any new construction in Jamestown.
- Designate FEMA "Critical Facilities" in Jamestown in accordance with the criteria in the ordinance. As identified in the 2015 HIRA, critical facilities include the Town Hall, Fire Hall, Upper Bridge, Lower Main Bridge and the Water Treatment Plant. Additional facilities may include health clinics and the school. As new facilities are developed in town, update the critical facilities designation as warranted.

8.1.2 Policy Recommendations

Policy recommendations for the town include consideration of a drainage setback policy and a stormwater conveyance and quality policy.

The drainage setback policy would pertain to James Creek and Little James Creek as well as the larger tributary drainages within Jamestown limits. While James and Little James Creeks have regulatory floodways restricting development in these areas, the tributary drainages do not. The setback policy would not only prevent encroachment of drainage conveyance and high hazard areas but also helps protect streamside habitat. Stream side areas may also be used for stormwater quality facilities and potentially a multi-use public trail facility. This policy would work well in conjunction with recommended updates to Ordinance 2 (Subdivision Ordinance).

A policy to improve stormwater conveyance and quality throughout Jamestown would be a first step towards overall drainage improvements. The policy should focus on the reduction of erosion from local storm drainage and establishment of formal and functional storm drainage conveyance systems. This policy would work well in conjunction with recommended updates to Ordinance 2 (Subdivision Ordinance). Reduction of erosion may be accomplished in many ways, depending on each situation, and the policy should avoid specifying means-and-methods. However, in general, concentrated flows need to be collected in a formal drainage system (whether surface or subsurface) and conveyed in a safe and non-erosive manner to James or Little James Creeks. Secondarily, the Town may also encourage the use of Low Impact Development (LID) stormwater methods for new public and private development, with the caveats described in Section 7.1, that filtration based LID practices struggle in environments with high sediment loading. With that said, LID practices are easier to implement than conventional end-of-pipe stormwater facilities and will reduce the impact of minor storm events in terms of both water quantity and quality.

8.2 Annual Considerations for the Town

The Town of Jamestown currently has a set of ordinances to integrate floodplain policies, flood and erosion control requirements, and enforcement into the growth and development of the Town. From an engineering perspective, these ordinances provide an adequate framework for the Town to implement, administer and enforce floodplain and drainage requirements. The challenge will be the cost and determination to keep drainage issues as a primary consideration as the Town continues to recover from the 2013 flood event and the memories of the extensive impact fade.

The Town could consider a dedicated creek setback for additional protection as a storm water management area and multi-use public trail facility. The Town can also encourage the use of LID ("low impact development") storm water techniques for new public and private development within the tributary area to reduce the impact of minor storm events in terms of both water quantity and quality.

Increasing the public's understanding of stormwater issues is key to the success of an expanded stormwater program. The Town may plan education sessions for storm water safety, conveyance and water quality treatment with posters or flyers that are economical to produce and can be used to distribute information to residents; use existing groups such as Left Hand Watershed Oversight Group and James Creek Watershed Initiative (JCWI) to deliver the floodplain message to their constituents.

On an annual basis, the Town should revisit the following items to maintain and improve drainage and stormwater management. An open work session once a year, on these issues, would help keep them as a Town priority.

- Allocating budget for floodplain administration, potentially as a contract service.
- Create and maintain a capital improvements plan with a list of major and minor projects, prioritizing critical work followed by important work.
- Include drainage projects in the annual Roads and Bridges budget or establish a specific budget dedicated to drainage projects.
- Monitoring of drainage issues. It is easier to address small problems before they become major problems. Monitoring locations should include two categories of sites: stream side and local drainage. The master plan maps in the appendix of this report point identify specific areas where erosion, scour, and debris collection would be most expected to occur.
- Collection and notation of new issues and reporting to Town Board on a regular basis.
- Stay current with best and new stormwater practices in Colorado.
- The Town Board of Trustees should annually re-evaluate the town policies, ordinances, and procedures to assess if they are meeting the goals of this plan.

9.0 Funding Opportunities

Improving Jamestown's drainage and stormwater management infrastructure, and making life even better for the residents of Jamestown are goals for the Town. These improvements require investments of time, energy, and money. Ayres' approach is to develop a grant strategy aligned with the goals of the Town and the recommended drainage projects.

In addition to writing a compelling grant narrative to win grant funding, it is important to strategically think of the horizon of projects the Town is contemplating and evaluate funding sources that "best fit" these projects regarding competition, timeline, sources and uses for match, demographics, and historical context. Creative funding strategies can be used to couple drainage improvements with other community enhancing improvements. For example, park improvements at the Town Square, completed during the summer of 2017 across from Town Hall, used both FEMA funds and GOCO grant funds. Working together, these grants provided funding to both regrade the area to improve drainage characteristics and construct park improvements.

The following is a suite of potential funding sources for the Town that may provide sources of funding for local drainage improvements, recognizing the challenge of finding funding partners for these types of projects. Several these funding sources may not be directly related to drainage improvements, however if utilized for other Town improvements, they could include drainage improvements as a secondary component to the larger project. The top three grants recommended for further investigation for eligibility, fund availability, and grant application preparation are marked with an asterisk (*).

9.1 Community Development Block Grants (CDBG)*

CDBG Planning Grant Program (CDBG-PLNG) can provide funding to help develop strategies for addressing specific needs and help fund local plans designed to improve the quality of life of the community and/or a wide variety of unique community development needs.

CDBG for Public Facilities (CDBG-PF) can help fund infrastructure and public building projects.

CDBG Public Facilities for Economic Development (CDBG-PFED) for roadway and infrastructure projects.

A minimum of 70% of CDBG funds go to predominately low- and moderate-income neighborhoods, which Jamestown qualifies as, and addresses conditions that present a serious and immediate threat to the health and safety of the community. Eligible uses of CDBG Public Facilities include acquisition, design / engineering, construction, reconstruction, rehabilitation or installation of public improvements or public facilities.

State administered CDBG funds are allocated on an annual basis. Eligibility research is required and applications are generally due in the fall of each year.

Web links

https://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopmetn /programs

https://www.colorado.gov/pacific/dola/community-development-block-grant-cdbg

9.2 Community Readiness Grants

Community Readiness Grants can help fund infrastructure to prepare a community for future business development.

9.3 Community Enhancement Grants

Community Enhancement Grants can help fund projects providing an "aesthetic character or quality of life" improvements that will create a business-friendly environment.

9.4 Small Business Innovation Research (SBIR)

Small Business Innovation Research can provide funding for site assessments.

9.5 U.S. Department of Agriculture Rural Development Grants*

U.S. Department of Agriculture Rural Development Planning Grants can be used by local governments to develop and adopt comprehensive plans.

Rural Development Water and Wastewater Program Grants can provide funding for community water, sewer, storm sewer, and solid waste systems.

Further discussion with the local Colorado State Office is the next step to determine what funding may be available.

9.6 Downtown Colorado Inc (DCI)

DCI is a nonprofit organization committed to building better communities through technical assistance to town centers and is currently partnering with Rural Development to provide funding to help communities develop their capacity to undertake housing, community facilities, and community and economic development projects.

9.7 Colorado Department of Transportation (CDOT)

CDOT Flexible Funding Programs – Surface Transportation Block Grant Program can help fund bicycle and pedestrian projects.

Transportation enhancement grants can help fund projects that enhance surface transportation facilities. Drainage improvements are often needed and can be associated with surface improvements, whether it is roadway improvements or pedestrian and bicycle paths/trails.

9.8 DOLA REDI Grants

Rural Economic Development Initiative grant can provide funding for local government economic planning grants and for infrastructure that supports economic diversification.

9.9 U.S. Environmental Protection Agency (EPA)*

EPA 319 Non-Point Pollution Control Stormwater Grants support non-point source implementation projects such as constructed wetlands and erosion control/debris control projects.

EPA-319 NPS funding requires a 40% match. Projects must include the EPA Nine Elements of a Watershed-Based Plan by constructing on-the-ground BMPs to address nonpoint source impacts from selenium, pathogens and/or nutrients to waterbodies not meeting water quality standards. Further research is required to determine whether James Creek and Little James Creek meet eligibility requirements. To the extent that pathogens and/or nutrients are attached to the debris, which could be likely, this project may meet eligibility guidelines under the NPS program.

Applications are generally due by January of each year.

9.10 Colorado Water Conservation Board (CWCB)

CWCB can assist with water resources and habitat restoration projects.

9.11 Great Outdoors Colorado (GOCO)

GOCO can provide funding for trails and community park amenities, playgrounds, and property acquisitions and conservation easements. Any park improvements that may be contemplated by the town may include drainage improvements

9.12 Greening America's Communities

Greening America's Communities can assist with implementing environmentally friendly neighborhoods that incorporate innovative green infrastructure and other sustainable design strategies.

9.13 Building Blocks for Sustainable Communities

Building Blocks for Sustainable Communities can provide targeted technical assistance to spur growth and development.

9.14 Energy / Mineral Impact Assistance Fund Grant

Drainage improvement projects that are related directly to roads impacted by the energy and mineral industry or where a safety hazard has been identified will be considered. Curb, gutter, valley pans, culverts, etc. are eligible for street and road projects when coordinated with a road or street improvement.

9.15 Funding Recommendations

These grants combined with some potential corporate sponsorships can be strategically pursued to fund a prioritized capital improvements projects list. Additional databases are also available to help narrow the search for possible funding sources, such as GrantSpy.com. After identifying the short-term and midterm projects, the Town can determine which opportunities align with the Town's funding initiatives.

Of the funding opportunities reviewed, there are the three opportunities recommended to concentrate on, that apply to the debris flow and local storm drainage projects. All require additional effort and meetings with the local state offices to determine eligibility and available funding programs, with follow up work to prepare grant applications.

- Community Development Block Grants (CDBG)
- EPA 319 Non-Point Pollution Control Stormwater Grants
- U.S. Department of Agriculture Rural Development Grants

With this information in hand, the Town can then decide if they wish to pursue grant funding research, grant proposal development, and grant administration. The Town can enlist a qualified consultant to further develop a grant strategy, pursue identified grants and administer grant funding sources.

10.0 Prioritize Drainage Solutions and Mitigation Measures

The ten resiliency criteria presented in Section 1.1 were used to develop prioritization criteria to use in a MCDA (Multi Criteria Decision Analysis) matrix. This tool is designed to develop discussion about important factors to consider when developing drainage solutions and assists in prioritizing these solutions into a list. The matrix is a tool to be used to assist in decision making. Project ranking can change over time as priorities change, funding becomes available, or new needs arise. It is meant to inform priorities, not set them in stone.

10 Resiliency Criteria Multiple benefits Collaborative approach High risk and vulnerability Social equity Environmental benefit Technical soundness Innovation Adaptive capacity Harmonize with existing activity Long-term and lasting impact

→

Prioritization Criteria Life Safety Structure Damage Access Impact Existing Maintenance Efficiency Grant Funding Potential Project Maintenance Construction Cost Water Quality Benefit

Drainage issues presented in Section 4.0 were grouped into projects as seen in Section 5.0. Each project was run through the matrix. A project was given a score from 1 to 5 for each criterion in the matrix. If a project was deemed critical for a given criterion, meaning that it impacted or protected critical facilities (i.e. water treatment plant, emergency access in and out of town), it could receive a score of 10. For each criterion, the score is multiplied by an importance factor to get a weighted score. Each criterion is assigned an importance factor based on its relative importance to the other criteria. The weighted scored for each criterion are added together and divided by the total of the importance factors to give an overall project score. This score is then multiplied by a factor based upon the water quality impact the project provides. The conceptual design of each project has considered its water quality impact. Debris drainage improvements are intended to improve or maintain existing levels of water quality as they convey storm water runoff to the creek.

The MCDA matrix is shown in Table 10-1, and Table 10-2 tabulates the scoring results of each project.

Table 10-1. MCDA Matrix

Criteria	Critical* (10)	ıl* (10) High (5) Medium (3) Low (1		Low (1)	Project Score	Importance Factor	Weighted Score	Range		
Life safety	Potential loss of life	Significant safety issue	Moderate safety issue	Minimal safety issue	e 5			0-25		
Structure Damage	Damage to WTP	Significant threat of property damage	Moderate threat of property damage	Minimal threat to property damange		4		0-20		
Access Impact	Prevents access to/from Town	Impacts emergency access	Impacts roadway access	Impacts driveway access		4		0-20		
Existing Maintenance		After every storm event	Several times per year	Annual or less		3		0-15		
Efficiency	Project protects critical facilities	Project has impact on larger area of town	Project addresses 2-3 drainage problems	Project addresses one drainage problem	s one 3 em			0-15		
Grant Funding Potential	Grant funding secured	High potential to receive funding	Medium potential to receive funding	Low potential to receive funding	2			0-10		
Project Maintenance	No maintenance required	Reduced maintenance effort	No change in maintenance effort	Increased maintenance required		2		0-10		
Construction Cost	No cost	Low cost	Medium Cost High Cost 1			0-5				
* Critical score is reserved for projects that protect critical facilities: water treatment plant, water distribution system, emergency access in 24										

* Critical score is reserved for projects that protect critical facilities: water treatment plant, water distribution system, emergency access in or out of town.

Water Quality			
Factor			
1.0	Does not improve WQ	Weighted Score	0-5
1.1	Improves WQ with significant maintenance requirements	Water Quality Factor	1.0 - 1.2
1.2	Improves WQ with low maintenance requirements	Overall Score	0-6

Table 10-2. MCDA Scoring Results

Jamestown Stormwater Master Plan MCDA												
Local Drainage Projects			Criteria Assessment Scores									
Project Rank	Project Name	Life Safety	Structure Damage	Access	(Ex) Maint.	Benefit	Grant Funding	Proj. Maint.	Const. Cost	Sub Total	WQ Factor	Total
1	Debris Flow Projects - Drainages C, D, F	5	5	10	3	10	3	3	1	5.71	1.2	6.85
2	C2 - 16th Street (Pipe Replacement)	3	1	3	5	5	3	5	1	3.25	1.2	3.90
3	C3 - 16th Street (Rehab)	3	1	3	5	5	3	5	3	3.33	1.1	3.67
4	C1 - Andersen Hill (Erosion Protection)	3	1	3	5	5	3	5	3	3.33	1.1	3.67
5	D - James Canyon Rd - High to 15th Street	1	3	1	5	3	3	5	3	2.67	1.2	3.20
6	F - 12th St Mesa to Main St. (Grading, Swale)	1	1	3	3	3	3	5	5	2.50	1.1	2.75
7	G - Buffalo Gulch Outfall	1	5	1	5	1	3	3	5	2.67	1.0	2.67
8	B1 - Merc/Town Hall (Drainage Pipe)	1	3	3	3	1	3	3	3	2.33	1.0	2.33
9	E - Main St East of James Creek (Grading)	1	3	1	3	3	3	3	5	2.33	1.0	2.33
10	H - Spruce Street (Grading)	1	3	1	3	3	3	3	5	2.33	1.0	2.33
11	A - Main St Ward to Howlett's	1	1	3	1	5	3	1	3	2.08	1.1	2.29
12	B2 - Merc/Town Hall (Cross Pan)	1	1	3	3	3	3	3	1	2.17	1.0	2.17
Importance Factor		5	4	4	3	3	2	2	1	24		

As the matrix shows, the high-ranking projects include the Debris Flow Projects for Drainages C, D, and F along Little James Creek, the 16th Street improvements (Projects C2 and C3), the Andersen Hill erosion protection (Project C1), and the James Canyon Road improvements – High to 15th Street (Project G). The water quality factor improved the scores of each of these projects.

The debris flow projects received particularly high scores for life safety, the protection of structures and access, and multiple benefit. Although the 16th Street improvements and the Andersen Hill erosion protection did not score as high, they too showed multiple benefits and contributed to life safety and protection of access to the south area of town.

Based on the ranking, the Town may want to focus efforts on these projects. A more detailed level of design for the drainage projects has been presented in this master plan (Section 5.1). Additional information for the cost of the debris fences are included in Section 6.0 and in Appendix D. The Andersen Hill project and the options for the 16^{th} Street drainage also received a higher level of design as described in Section 5.2.4 – 5.2.6 and seen in Appendix I. The plan presents two approaches for addressing the 16^{th} Street area and either approach may be done in phases to allow the overall project to be constructed over time and as funds allow. The project matrix can be used as a guide for grant preparation as it shows areas of concern, the goals of the Town, and the potential benefits of the project.

Although the other projects did not rate as high as the ones noted above in this section, they still add improvements to the overall town drainage system. Descriptions on approaches for these projects are presented in Section 5.2. General cost estimates can be found in Section 6.0 and in Appendix J. Additional recommendations for community education and signage on drainage issues and response, and an early warning system can be found in Section 5.1. Some of these projects are relatively less expensive than others and may be able to be completed with small grants or with the Town's regular roads and bridges fund.

11.0 Conclusions

11.1 Debris Flow

The recommended mitigation actions address the devastating effects the September 2013 debris flows had on the Jamestown community and are only intended to reduce the impacts of future debris flows with a magnitude of 50% less than what was realized in 2013. Lithos identified three drainages north of Town, defined as Drainages C, D, and F, that are believed to pose the greatest risk to town residents, and have a high likelihood of conveying debris flows in the future.

Lithos recommends the installation of three relatively evenly spaced GeobruggTM VX160-H6 ring net barriers, or equivalent, in Drainages C and F, and the installation of four relatively evenly spaced GeobruggTM UX180-H6 ring net barriers, or equivalent, in Drainage D. Lithos also recommends the construction of a detention basin and headwall for the proposed culvert at the base of Drainage D to provide additional debris protection to the roadway and Little James Creek. Recommended barrier types, quantities, spacing, and locations is preliminary. A detailed survey of the drainage channel at proposed net locations is still required to accurately size barriers and determine retention capacities. The estimated comprehensive mitigation costs for Drainages C and F is just over \$500,000 each, and just over \$1 million for ring net barriers in Drainage D, and approximately \$325,000 for the detention basin headwall structure at the base of Drainage D. The cost estimates include materials, construction, and contingency to incorporate anticipated and unanticipated challenges due to the relative remoteness and challenging terrain of the drainage channels.

The final design of the barrier systems should consider utilizing viable portions of Drainages D and F on USFS land to increase retention capacity and further mitigate risks. Lithos contacted the USFS for Boulder County and were advised that the possibility of installing ring nets on their land could not be deemed impossible at this stage, however approval would likely require permit applications, an environmental impact study, and an access agreement for construction and maintenance. The USFS has also conveyed informed us, not unexpectedly, that the Town would be responsible for covering the costs for the environmental impact study which would include, at a minimum, analysis of the barriers' impact on wildlife, botany, heritage (archeology), visuals, soil, and hydrology. Therefore, construction of debris flow mitigation systems on USFS land may be cost prohibitive and/or not approved. Lithos has also recommended the continuation of and/or the implementation of new mitigation actions such as an early warning system, increased signage along the roadways, land acquisition for properties in high-risk areas, community education, and support for emergency response personnel.

11.2 Local Drainage

Jamestown lacks a formal drainage conveyance system and this results in periodic localized flooding of roadways and structures and erosion issues. The recommended solutions in this master plan attempt to solve multiple issues such as conveyance, local flooding, erosion, infrastructure damage, and transportation impediments while taking into account the established resiliency criteria and low impact design where possible.

The master plan identifies and provides solutions for the local drainage issues presented to the master plan team. In many cases, individual components of each project could be constructed independently and allow the improvements to be built in phases or as opportunity and/or funding arises.

Based on the prioritization criteria developed during the plan process, priority areas to address include Andersen Hill, the 16th Street system, and the High Street to 15th Street area. Although all the solutions recommended in the plan will benefit the town in some way, special attention should be given to these priority areas for they address many of the goals and objectives of this plan.

11.3 Creeks

The hydraulic analyses of James and Little James Creeks were performed with the SRH-2D model (version 12.2) as implemented in the Aquaveo SMS software. This analysis considered stream inflows upstream of Jamestown and mapped approximate flood inundation limits for four streamflow frequencies: the 10-, 25-, 50-, and 100-year events.

The creek channels reach bank full capacity just below a 10-year event and begin to come out of channel at the 10-year event between 85 and 91 Main Street and flow down Main Street to the Main Street bridge. At the 25-year event, flows exit the channel near the water treatment plant and travel down Ward Street to the Ward Street bridge.

Erosion potential was also analyzed for the same four streamflow frequencies with the following summary of results.

- For flows up to the 10-year event, the creek channels appear to be relatively stable.
- Potential minor erosion issues and bank instability begin to surface at the 10-year event with some localized areas of erosion downstream of the confluence and many spots upstream of the confluence on both James and Little James Creek.
- At 25-year flows, much of both channels upstream of the confluence are likely to begin to erode with increased erosion downstream of the confluence.
- At flows nearing the 50-year event and above, reach level instability is likely to be observed.

Because James Creek has recently undergone significant man-made changes, it can be expected that natural changes will be seen in the coming years. The creek will naturally transport material from areas of high shear stress as it finds a "new normal" condition. A good practice would be to walk the entire reach at least once a year and especially after high flow events, documenting and photographing any changes that are seen. Special attention should be given to the drop structures, watching for erosion on the outer ends where it ties into the bank. If the boulders keyed into the bank become exposed, this could lead to the failure of the entire structure and rapid bank erosion.

On Little James Creek, it will be important to maintain capacity in all culverts. These should be maintained on a regular basis, clearing out debris and sediment build up as these will decrease the culvert's capacity to transport flow and could lead to a clogged condition, causing overtopping and possibly road/bridge failure. This applies to all culverts and inlets, but especially those in the main channels. To maintain awareness of flow conditions in James Creek it is recommended that a visual flow gage be installed in a highly visible location on the bedrock downstream of Andersen Hill Bridge and across from the Town Square.

11.4 Stormwater Management

The primary challenges for stormwater management for Jamestown are the steep slopes, lack of space for larger stormwater facilities, and lack of formal drainage systems. Conventional "end of pipe" water quality treatment methods, such as extended detention water quality ponds (sedimentation ponds), are not feasible here due to the steep terrain and limited space.

Stormwater quality management strategies for Jamestown should be focused around erosion prevention and conveyance of stormwater in proper drainage systems. It appears that the largest water quality issue in Jamestown is high sediment loading from local erosion due to steep slopes, concentrated flows and lack of formal or adequate drainage systems. Low Impact Design (LID) methods do not require large amounts of space. However, LID strategies which are primarily filtration based, such as permeable paving, rain gardens, and bio-retention, do not work well in high sediment loading situations. Their applicability and successfulness in Jamestown would be limited and would require frequent maintenance. LID strategies that are straining-based, such as grassed swales and grassed filters or buffers, may work well in Jamestown.

Recommended strategies to reduce erosion and improve stormwater quality for Jamestown include:

- Collect concentrated flows in appropriate and adequate storm drainage pipes or surface swales. (Eliminate the water sources of erosion before erosion occurs.)
- Install riprap erosion protection in areas of frequent erosion.
- Grassed swales.
- Grassed filter or buffer strips.
- For swales with erosion problems, consider riprap linings and rock checks. If this is not sufficient, a concrete swale or piped drainage system may be necessary.
- Re-vegetate barren areas and maintain healthy vegetation around surface swales.
- Consider Low Impact Development (LID) strategies that are applicable (i.e. straining based BMPs: grassed swales, and grassed filters/buffers).
- Install concrete sediment forebays where possible.
- Street sweeping (James Canyon Drive) and storm drain pipe cleaning (jet-vacuuming) are BMPs that may be practical for Jamestown.
- Promote pollution prevention (illegal dumping and discharges) and "good housekeeping" methods, such as covering outdoor storage and chemical storage areas.

The locations of stormwater quality management systems may occur where pipes flow into the creek or along the roadsides – both on private and public properties. It is recommended that the Town work with private property owners as well as consider Town-owned land to find appropriate locations for LID solutions. It is also recommended that the Town continue to work closely with area watershed groups such as the Left Hand Watershed Oversight Group and the James Creek Watershed Initiative to monitor water quality in the area and design and develop stormwater management projects.

11.5 Funding

The limited Town budget for maintenance and drainage improvement projects highlights the need for outside funding, ideally grant funding. A number of funding sources have been identified and the following three are the most viable candidates for further pursuit to identify the town's eligibility,

understand funding availability, and prepare applications to fund debris flow and drainage improvements projects. These three are:

- Community Development Block Grants (CDBG)
- EPA 319 Non-Point Pollution Control Stormwater Grants
- U.S. Department of Agriculture Rural Development Grants

11.6 Town Policy

Review of the Town's existing Ordinances identified several recommended updates to address stormwater and drainage topics. Policy recommendations for the town include consideration of a drainage setback policy and a stormwater conveyance and quality policy.

On an annual basis, the Town should revisit the following items to maintain and improve drainage and stormwater management. This would help keep them as a Town priority.

- Allocate budget for floodplain administration, potentially as a contract service.
- Create and maintain a capital improvements plan with a list of major and minor projects, prioritizing critical work followed by important work.
- Include drainage projects in the annual Roads and Bridges budget or establish a specific budget dedicated to drainage projects.
- Monitoring of drainage issues. It is easier to address small problems before they become major problems. Monitoring locations should include two categories of sites: stream side and local drainage. The master plan maps in the appendix of this report identify specific areas where erosion, scour, and debris collection would be most expected to occur.
- Collection and notation of new issues and reporting to Town Board on a regular basis.
- Stay current with best and new stormwater practices in Colorado.
- The Town Board of Trustees should annually re-evaluate the town policies, ordinances, and procedures to assess if they are meeting the goals of this plan and priorities of the Town.

12.0 Limitations

12.1 Design Limitations

The hydrologic and hydraulic analysis and the conceptual design effort for drainage improvements are meant to provide information and guidance for the Town. The proposed projects have been developed at a conceptual level and final design engineering efforts are needed prior to constructing these improvements. The analysis of the creek and assessment of erosion potential is meant to give the Town a tool to assist in anticipating, identifying, and responding to issues related to high creek flows and does not guarantee where erosion problems or flooding issues will occur in the future. Cost estimates for drainage improvements should not be considered comprehensive, however, Ayres included contingencies to account for potential challenges and design refinements that likely will occur during final design

12.2 Geotechnical Limitations

The purpose of the debris flow assessment was to provide an evaluation of debris flow hazards and corresponding mitigation options for the Town. The report was based on information gained through preliminary investigative methods. Recommendations presented herein should be regarded as preliminary, and for the sole purpose of identifying high-risk drainages and estimating magnitude of cost for recommended mitigation options. No debris flow mitigation systems will provide complete protection to life and safety of the public or property. The report assumes the completion of comprehensive barrier designs once funding is secured. Debris flow barriers are complex structures that require careful assessment and detailed design. The DEBFLOW software utilized in this report is a dimensioning tool for planning purposes only and is only approved for preliminary design. Information and data in the software is based on principled equations and safety concepts according to technical documents, dimensioning concepts, product manuals, and installation instructions and it cannot be totally excluded that there are errors in the program. Cost estimates should not be considered comprehensive, however, Lithos included contingencies to account for potential challenges such as difficult site access, difficult construction conditions, permitting, and adjustments to the standard barrier designs.

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principals; no warranty, expressed or implied is made. This report has been prepared exclusively for our client for recommendation purposes for the subject project. Lithos Engineering is not responsible for technical interpretations by others of the data presented in this report or use of this report by others for the subject project or other projects. If differing site conditions are encountered during further evaluation by others or during construction, Lithos Engineering should be notified immediately to determine if any changes to our recommendations presented in this report are warranted.

An environmental assessment was not included in Lithos Engineering scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If the client is concerned about the environmental conditions at the site, Lithos Engineering recommends the client and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

13.0 References

- AECOM Memorandum- Hydraulic Design for James Canyon Drive Flood Recovery, October 2016.
- DEBFLOW Software Manual-Debris Flow Protection, Geobrugg AG, April 2017.
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- Hazard Identification and Risk Assessment, Housing and Land Use Analysis-Town of Jamestown (HIRA), Leese & Associates, December 2015.
- Hazard Mitigation Plan (HMP)-Boulder County, Boulder Office of Emergency Management, 2015.
- Highland et al., 2016, Debris Flow Hazards in the United States Fact Sheet, United States Geological Survey-U.S. Department of the Interior
- Town of Jamestown Source Water Protection Plan Boulder County, CO, Colorado Rural Water Association, September 2011
- Jamestown Emergency Watershed Protection Project As-Built Plans AMEC, 2014
- James Canyon Drive Permanent Repairs Boulder County Transportation Department Engineering Division, 100% Plans, October 2016
- Town of Jamestown LOMR Submission CWCB Contract #CT 2016-1452, AECOM, May 2016